TYDEIDAE OF CITRUS FROM SELECTED COUNTRIES: DISTRIBUTION, SEASONAL OCCURRENCE, RELATIVE ABUNDANCE, AND FEEDING HABITS (ACARI: PROSTIGMATA)

By

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my eyes were finally opened
and I understood nature;
I learned at the same time to love it.

Claude Monet

To be what we are,
and to become what
we are capable of becoming,
is the only end in life.

Robert Louis Stevenson

This work is dedicated to my father
and to the memory of my mother, for
all the love, affection, confidence,
guidance, and support that I have
received always, which have given
me the strength to confront the
challenges of life.

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y a la memoria de mi madre, por
todo el amor, afecto, confianza,
guía y apoyo, que he recibido siempre,
y que me han dado la fortaleza para
enfrentar los desafíos de la vida.

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TYDEIDAE OF CITRUS FROM SELECTED COUNTRIES: DISTRIBUTION, SEASONAL OCCURRENCE, RELATIVE ABUNDANCE, AND FEEDING HABITS (ACARI: PROSTIGMATA)

By

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Surveys were conducted to identify the Tydeidae on citrus orchards in Florida, Texas, Louisiana, and selected countries, i.e., Bahamas, Brazil, Dominican Republic, Italy, Morocco, Portugal and Spain. The citrus habitats sampled were inner and outer leaves, immature and mature fruit, inner and outer twigs, and flowers and brushings from the tree trunk. Tydeids were collected on 42 ground cover plants of more than 80 sampled in those orchard sites not using herbicide programs.

Nine tydeid species were identified from the surveys: *Lorryia formosa* Cooreman, *Tydeus californicus* (Banks), *T. gloveri* (Ashmead), *T. munsteri* Meyer & Ryke, *Pseudolorryia mumai* (Baker), *Paralorryia shawi* (Baker), *Parapronematus acaciae* Baker, *Apopronematus* sp., and *Metapronematus* sp. *Lorryia formosa* was the prevalent species collected in Florida, ranging from 43,000 mites in Mixon II to 433,000 in Pollard on the eight combined habitats throughout the season. The frequencies of *L. formosa* ranged from 65% in Mixon I to 98.5% in Pollard. The highest densities of *L. formosa* were observed on leaves. *Tydeus gloveri* ranged second in abundance in the Trask

orchard. *Pseudolorryia mumai* comprised 20% of the total tydeid population in the Mixon I orchard. *Parapronematus acaciae* was more abundant in Mixon II with 13% of the total population. *Paralorryia shawi*, *T. californicus*, *T. munsteri*, *Apopronematus* sp., and *Metapronematus* sp. were found in low numbers. The tydeid populations peaked between April and May, and were found in low densities between July and October, when the populations began to increase again. *Lorryia formosa* was the only species found on all citrus habitats sampled. Tydeid species associations were common in most of the habitats, e.g., *L. formosa*, *T. californicus*, and *T. gloveri* were important leaf dwellers. *Lorryia formosa* was found associated with *T. gloveri* and *P. mumai* on twigs, and with *P. shawi* and *Apopronematus* sp. on tree trunks. *Parapronematus acaciae* was also found on twigs.

Feeding studies demonstrated that the tydeid species evaluated had preferences for certain fungi on citrus trees. *Colletotrichum* sp. served as a food source for *P. mumai* and *P. acaciae* and was found in the digestive tracts of *L. formosa*, *T. californicus* and *T. gloveri*. *Penicillium* sp. was found in the digestive tracts of *L. formosa* and *T. californicus*. *Lorryia formosa* was observed feeding on *Malephora crocea* Jacques, *Typha domingensis* Persoon and *Quercus* sp. pollens, and *T. californicus*, *T. gloveri* and *L. formosa* were maintained on a diet of ice plant pollen and sugar water. *Lorryia formosa* females were observed feeding on eggs and early immature stages of *Aculops pelekassi* (Keifer) but would not feed on *Phyllocoptruta oleivora* (Ashmead). *Lorryia formosa* was found associated with scale insects, mealybugs, and detritus on citrus leaves and twigs, where this tydeid species aggregated.

CHAPTER 1
INTRODUCTION

Citrus is an economically important crop in Florida with 336,817 ha of which 80% are oranges, 14% grapefruit and 6% specialty fruit (Florida Agricultural Statistics Service 2000). The most important citrus-growing regions in Florida are located in Polk, Hendry, Highlands, DeSoto, Hardee, St. Lucie, Indian River, and Martin counties. These 8 counties comprised about 75% of the total citrus production in Florida (Florida Agricultural Statistics Service 2000).

Several species of mites are associated with citrus in Florida, and some can cause significant damage and yield losses if control decisions are not promptly taken. For instance, the citrus rust mite (CRM), *Phyllocoptruta oleivora* (Ashmead) (Acari: Eriophyidae), has a worldwide distribution and is considered to be the most serious pest on Florida citrus (Childers 1994, 1997; Browning et al. 1995; Childers et al. 1996; Childers & Achor 1999). This mite feeds upon the epidermal cells of citrus fruit and causes a discoloration known as sharkskin, russet, or bronzing, depending upon whether damage occurs in the early, mid or late stages of fruit growth (Albrigo & McCoy 1974; Allen 1976, 1978). Defoliation can increase from severe feeding damage, especially when combined with dry weather (McCoy 1976), and fruit drop increases with rust mite damage (Allen 1978). There is also a reduction in the growth rate of oranges and grapefruit by citrus rust mite damage (Allen 1979). Another species that can be of economic importance is the pink citrus rust mite, *Aculops pelekassi* (Keifer) (Acari: Eriophyidae), which also is distributed worldwide. In addition to reduction in cosmetic

appearance to fruit by feeding, sustained heavy populations of rust mites can reduce fruit size and thus reduce yields (Albrigo & McCoy 1974; Allen 1978, 1979; Browning et al. 1995; Childers & Achor 1999). Pink citrus rust mite co-exists on leaves and fruit with *P. oleivora* (Childers & Achor 1999) and is capable of inducing other leaf damage including leaf distortion, mesophyll collapse, and leaf drop (Seki 1979).

Muma (1958) and Childers (1994) reported that citrus in Florida was susceptible to feeding damage by other important acarine species in the Tetranychidae, Tenuipalpidae and Tarsonemidae. A summary of the major pests includes spider mites (Tetranychidae) with the Texas citrus mite, *Eutetranychus banksi* (McGregor), being the most important species in Florida. The citrus red mite, *Panonychus citri* (McGregor) is second in importance in Florida although of great economic importance worldwide (Childers 1994). The six-spotted mite, *Eotetranychus sexmaculatus* (Riley), is a sporadic spring pest of occasional importance on Florida citrus (Childers 1994). The false spider mites (Tenuipalpidae) in the genus *Brevipalpus* are found on citrus in Florida and are not considered a problem in commercial citrus orchards in Florida at present (Childers 1994). The broad mite, *Polyphagotarsonemus latus* (Banks) (Tarsonemidae), is considered a serious pest on limes in southern Florida (Peña 1990, 1992; Peña et al. 1989; Peña & Bullock 1994).

Most of the efforts and investigations are directed to control rust mites since they are the most important mite pests on Florida citrus. Chemical control costs for *P. oleivora* range from 75-100 million dollars annually in Florida (Childers 1996).

Due to the high costs of chemical control, increasing production costs to growers, declining fruit prices, and the possibility of acquiring resistance to acaricides by

phytophagous mites (Childers et al. 1996), it is necessary to seek pest management alternatives. One option is the development of an Integrated Pest Management (IPM) program (Childers et al. 1996), which uses all the available resources associated with the citrus system. Biological control is one of its most important components. Current recommendations in the Florida Citrus Pest Management Guide consist solely of acaricides (Childers et al. 2001a, b). There is a rich fauna of natural enemies present on citrus (Muma 1975; Childers 1994, 1996) and potentially important species are in the Tydeidae. Our understanding of these mites is limited.

The Tydeidae are small (about 100-500 μm) prostigmatid mites, poorly sclerotized, that are found occupying diverse niches throughout the world (Kazmierski 1998b). The available tydeid literature deals primarily with taxonomic and systematic work, i.e., family reviews, species descriptions or taxonomic status. Information related to morphology and, to a lesser extent, ontogeny is found extensively in the literature. However, there is a lack of information about population dynamics, seasonal occurrence, or general ecology related to this family. Feeding studies with tydeid species are lacking. Most are based on limited field observations or speculation in commodities including citrus.

What are the roles of different tydeid species on citrus? Since so little is known about these mites on citrus worldwide several research objectives were pursued.

1) Identify tydeids associated with citrus in several orchards throughout Florida (in 1986 and 1987 and from 1997 to 1999), other citrus-growing states (Louisiana and Texas) and sites sampled in several citrus producing countries, i.e., Bahamas, Brazil, Dominican Republic, Morocco, Italy, Portugal and Spain.

2) Develop a dichotomous key to the Tydeidae found on citrus.

3) Identify the species of Tydeidae associated with citrus in seven selected orchard sites in central and south central Florida, between 1995 and 1996.

4) Determine the seasonal occurrence and relative abundance of Tydeidae in the seven selected orchards.

5) Contribute to information on the feeding habits of selected Tydeidae species in the citrus system.

CHAPTER 2
LITERATURE REVIEW

The Family Tydeidae (Acari: Prostigmata)

The Tydeidae (Acari: Prostigmata) are a cosmopolitan family of mites with over 200 described species in 42 genera (André 1980; Kethley 1990). They are generally ovoid in shape with color varying from yellow, brown, red, green, or beige to white, and relatively fast moving (Baker 1965; Salviejo 1969; Carmona & Silva-Dias 1996; Kaźmierski 1998b; Walter & Proctor 1999). Adults range in size from 150 to 500 μm and have weakly sclerotized or unsclerotized bodies (Baker 1965, Carmona and Silva-Dias 1996; Kaźmierski 1998b), although adults within the subfamily Pretydeinae have a well sclerotized body and are usually covered with rich ornamentation (Kaźmierski 1996a). Tydeid mites are often abundant and can be found throughout the world on various host plants such as bamboo, lichens, *Bixa* sp., *Citrus* sp., *Grewia robusta* Burch, *Jacobina* sp., *Maytenus nemorosa* (Ecklon & Zeyher), *Pappea capensis* Ecklon & Zeyher, *Pinus* sp., *Podocarpus usamburensis* Pilger (Kaźmierski 1996a).

Tydeidae are common in soil, humus, litter, on mosses, lichens, mushrooms, algae and grasses, on trees (on bark, leaves and fruit), on straw and hay, on stored products, more rarely in the nests of birds and mammals, and also on invertebrate animals – mainly insects as phoretic forms (Baker & Wharton 1952; Marshall 1970; Krantz 1986; Kaźmierski 1998b; Walter & Proctor 1999). Tydeidae are abundant in lawns, on mosses

covering rocks, as well as on xerothermic (characterized by heat and dryness) slopes (Kaźmierski 1998b).

Tydeidae occur in all continents, and in all climatic zones of the world (Kaźmierski 1998b). Some species are widely distributed while others are restricted to a particular habitat. The great majority of species are recorded only from one locality or from a few localities, and it is difficult to characterize their distribution or habitat preferences (Kaźmierski 1998b). Zoogeographical and ecological studies are needed to properly identify the habits of tydeids (Kaźmierski 1998b).

This review of the literature will deal with four major components, i.e., morphology and systematics, ecology, feeding habits and economic importance of the Tydeidae. The review will be oriented mostly to the tydeids occurring on citrus in Florida.

Morphology, Taxonomy and Systematics of Tydeidae

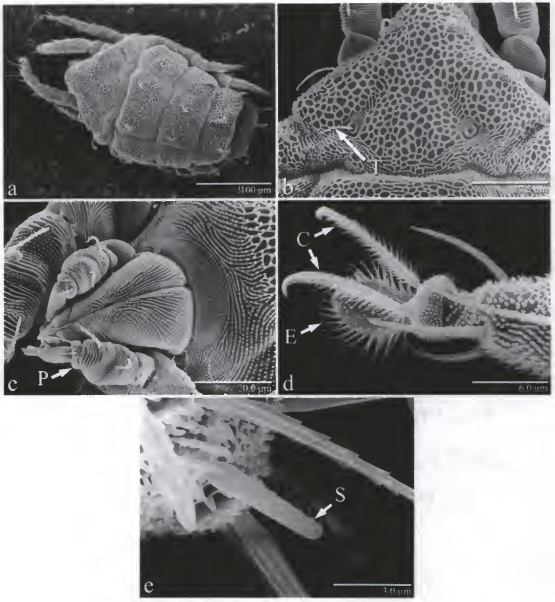
The family Tydeidae was established by Kramer in 1877 on the basis of an earlier described genus, *Tydeus* Koch, 1835. Revisions of the family were completed by Thor (1933), Baker (1965) and André (1980). Several studies were conducted on the taxonomic status of the family or a particular subfamily or subfamilies. The most relevant for our purposes are those by André (1980) and Kaźmierski (1998b) and cover the most extensive material on the taxonomy of the family. The classic works of Grandjean originally published in 1944 (republished in 1973a, b, c, d) were the foundation for the present basic knowledge concerning the morphology of tydeid mites (André 1979, Kaźmierski 1998b).

The body of tydeids (Fig. 2-1) is generally weakly sclerotized and many of the taxonomic features that should be taken into account to separate this family from other Prostigmata in the subclass Acari include 1) The leg trichobothria are absent, with only one pair of prodorsal trichobothria present; 2) the pretarsi II-IV are usually with paired claws and an empodium; 3) the sclerotization of the esophagous does not extend internally to the level of the prodorsum (shield); 4) the prodorsum has four or more pairs of structures present and peritremes are absent; 5) the rutellum (a shovel-shaped seta on the gnathosoma of primitive mites) is absent and the palps have four segments; 6) solenidia of tarsus I are erect, not recumbent; the famulus (chemosensory seta) and the naso (anteromedian propodosomal projection) are absent; 7) the solenidion of tibia I, when present, is not recessed into a pit (Kethley 1990).

Body: The body of a typical tydeid is composed of a gnathosoma (where the mouthparts are located) and the idiosoma (the rest of the body, including legs and the genital area).

Gnathosoma: The gnathosoma represents a highly evolved and specialized body region that includes two main segments: the cheliceral frame and the infracapitulum (composed of the hypostome and the palps) (André 1981a; Kaźmierski 1998b). The chelicerae are mostly fused (André 1981a), and composed of two parts: a fixed digit (digitus fixus) and a movable digit (digitus mobilis). The movable digit consists of the principal segment (basilar sclerite) and a stiletto (dagger, stylet) (Kaźmierski 1998b), which is articulated with the principal segment and bears a stylet that is birefringent and hollow (André 1981a). The palps are composed of four segments: trochanter, femurogenu (femur-genu), tibia and tarsus (Baker 1965, Grandjean 1973b; André 1981a). There are no setae on the palp trochanter.

Fig. 2-1. (a) Adult *Lorryia formosa* (dorsal view); (b) Prodorsal trichobothrium (T) of *L. formosa*; (c) Gnathosoma and pedipalps (P) of *L. formosa*; (d) Empodium (E) and tarsal claws (C) of tarsus II of *L. formosa*; (e) Solenidion I (S) of *L. formosa*.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Idiosoma: The idiosoma is divided into the aspidosoma (the region in front of the disjugal furrow) (Alberti & Coons 1999), podosoma and opisthosoma that includes the genital and anal areas, and holds four pairs of legs (Kaźmierski 1998b) (Fig. 2-2).

Legs: Each leg consists of six segments, excluding the coxa: trochanter, femur, genu, tibia, tarsus and pretarsus apotele. Chaetotaxy of the legs is the main generic feature in André's systematic concept (André 1981b; Kaźmierski 1998b) (Fig. 2-2).

Ornamentation. Ornamentation of the cuticle is a constant feature, or variable at least in limited measure in all stages. The development of research techniques, especially scanning electron microscopy, provides incredible resolution and detail of different morphological structures including ornamentation. There are two main categories of ornamentation in the Tydeidae: reticulation and striation. The species covered with a flat reticulum at least in the dorso-central region (between setae d_1) represents a "Lorryia" type. A separate type of reticulation is referred to as a "Mountains" type (Kaźmierski 1998b). Therefore, reticulation is divided into two types: "Lorryia" and "Mountains." Striation is represented by the following types: "Paralorryia" (with eight subtypes), "Tydeus," "Venilia" and "Basket weave" (Kaźmierski 1998b). The Lorryia type as described by Kaźmierski (1998b) is clearly shown in photographs by Becker (2000), Wergin et al. (2000) and Achor et al. (2001).

Chaetotaxy. The number and position of setae on the body and legs of Tydeidae, called chaetotaxy, is a crucial character in species identification.

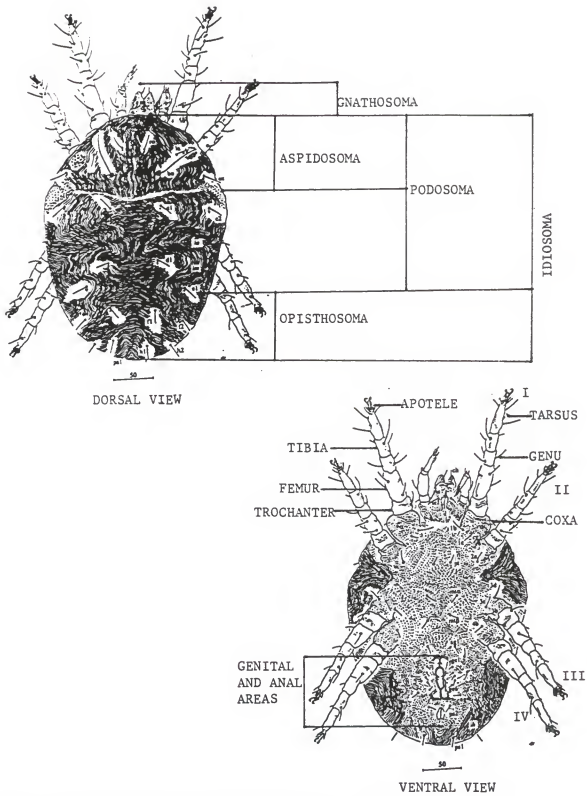


Fig. 2-2. Body division and major morphological characters in a tydeid mite. (Modified from Kaźmierski 1998b)

Ontogeny of Tydeidae. Seven stages exist in the ontogeny of Tydeidae: egg, prelarva (PL), larva (L), protonymph (PN), deutonymph (DN), tritonymph (TN), and adult (AD – female or male) (André & Fain 1991; Kaźmierski 1998b). The prelarva is calyptostatic (can neither move nor feed) in all Tydeoidea (André & Fain 2000).

General Description of Tydeidae

Recently, Lindquist (1998) considered Tydeoidea as a sister group of the Eriophyioidea, a very highly specialized phytophagous superfamily. This hypothesis is quite new and well demonstrated by a cladistic analysis of the phylogenetic relationships among major superfamilies or higher lineages of the Trombidiformes. Lindquist's approach was based on a series of inherited characters from their ancestral condition. Although a few tydeid species have been recorded as typical plant feeders, the remaining species have been described as omnivorous, saprophagous, fungivorous, or predacious on small arthropods and their eggs (Kaźmierski 1998b).

André (1980) divided the Tydeidae into seven subfamilies with 42 genera. The subfamily Tydeinae has the largest number of genera and species (Kaźmierski 1989, 1998b). André (1979, 1980) based his classification on organotaxy, which consists of chaetotaxy (distribution patterns and structure of setae), solenidiotaxy (distribution patterns and structure of solenidia) and poroidotaxy (number of lyrifissures, which are pores distributed on the tydeid's body). The Tydeinae are usually large or middle-sized (generally more than 150 μm) and comparable in size to species in the Eriophyidae and Tarsonemidae. Tydeid mites have diverse types of ornamentation, often richly sculptured and they occur in many habitats (Kaźmierski 1996b). André (1980) synonymized the

genus *Lorryia* into *Tydeus* and then the species *Lorryia formosa* Cooreman became *Tydeus formosus* (Cooreman), a name used by some authors in the past (Flechtmann 1987). André (1980) based his changes on the similarities of the chaetotaxy, especially on the legs, but ignored body ornamentation, which is a major character used by other authors. Kaźmierski's (1998b) revision of the Tydeinae of the world was based on the ornamentation characters and other features. He confirmed the specific status of *L. formosa* as originally described by Cooreman (1958). This subfamily is characterized by having three pairs of lyrifissures and a pair of primitive eyes (oculi) which commonly occur laterally on the propodosoma. The genital region includes a progenital aperture flanked by setae. Twenty one genera of Tydeinae have been described, excluding synonyms (Kaźmierski 1998b). Another important subfamily is the Pronematinae which was proposed by André (1979) and includes most of the known predacious tydeids, such as *Homeopronematus anconai* (Baker) and *Pronematus* sp. The Pronematinae consist of 50 species within 11 genera (Kaźmierski 1998a), and all share the reduction or loss of apotele I (André 1980; André & Fain 2000). The Pronematinae are characterized by having five very long eupathidia (chemosensory setae) on tarsus I, a procurved prodorsum, four pairs of lyrifissures, and no eugenital or genital setae (André 1979).

Evolution of Tydeidae

Current evidence suggests that eriophyoid mites are closely related to tydeid mites (Lindquist & Oldfield 1996; Lindquist 1998). Presumably plant feeding evolved from scavenging or fungus-feeding leaf vagrants that were opportunistic leaf cell feeders (as some modern tydeid mites are thought to be). This switch to obligate plant parasitism may have occurred in the Paleozoic Era (Walter & Proctor 1999).

Phytophagy in the Tydeidae appears to be a non-obligatory, incidental phenomenon that has arisen as an offshoot of fungivory. This in turn probably arose from a more generalized primitive predatory mode according to Krantz and Lindquist (1979). One would expect that tydeids, which have fused cheliceral bases, reduced fixed cheliceral digits, and needlelike movable digits, would be easily adapted to obligatory feeding on higher plants. However, no tydeids are obligate plant feeders (Krantz & Lindquist 1979). In general, the Tydeidae are unspecialized feeders with a propensity for phytophagy according to Krantz and Lindquist (1979). Their lack of specialization suggests that the family is in an evolutionary transitional phase, and that phytophagy may well be a major direction for future development (Krantz & Lindquist 1979).

Ecological Aspects of Tydeidae

Tydeid Mites and Their Habitats

Tydeids and leaf domatia. Domatia are small invaginations or hair tufts usually found at vein junctions on the underside of leaves in many woody Dicotyledonae (Pemberton & Turner 1989; Walter & O'Dowd 1995; Walter 1996). Domatia frequently serve as shelters and nurseries for mites that eat phytophagous arthropods and pathogens (Pemberton & Turner 1989; Willson 1991; Walter & O'Dowd 1992). Tydeids can be particularly abundant on plants that have leaf domatia, such as *Coffea arabica* L., *Canthium* sp., *Cinnamomum camphora* (L.), *Cryptocarya triplinervis* Brown, *Elaeocarpus longiflorens* [sic], *E. sphaericus* Schumann, *Guioa acutifolia* Mueller , *G. lasioneura* Radlkofer, and *Jasminum didymum* Forster (O'Dowd & Willson 1989). For example, Pemberton and Turner (1989) found that the domatia of 26 of 31 (84%) plants

had mite species considered beneficial (primarily in the families Phytoseiidae and Tydeidae, with Bdellidae, Cheyletidae and Stigmaeidae also present), while 6 of 31 (19%) had mite species considered harmful (Tenuipalpidae and Eriophyidae). Walter and O'Dowd (1995) found that most mites inhabiting leaf domatia on numerous tree species were fungivores, especially Tydeidae (unidentified species) and species in the suborder Oribatida.

The elevated number of mites on leaves with domatia suggests that plants could benefit in two ways. First, predacious and microbivorous (microbe-feeding) mites could reduce the effect of plant enemies including herbivorous mites and fungal pathogens (Grostal & O'Dowd 1994). Second, microbivorous mites, by grazing on phylloplane fungi (fungi which live on the leaf surface), could clean the leaf surface of epiphyllic growth, and consequently this could increase leaf photosynthetic efficiency (Rozario 1995; O'Dowd & Willson 1989; Pemberton & Turner 1989).

Norton et al. (2000) found that leaves of the wild grape, *Vitis riparia* Michaux, sustained high numbers of *Tydeus lambi* (Baker), often exceeding 100 individuals or more per leaf. These leaves possess acarodomatia (mite houses) that are frequently occupied by this tydeid mite. The authors found that domatia resulted in an increase in the number of *T. lambi* inhabiting the plant, which translated into a decrease in powdery mildew, an important foliar pathogen of cultivated and wild grapes (English-Loeb et al. 1999). They considered that both *T. lambi* and *V. riparia* benefited from this association.

Tydeids and Their Hosts

Tydeus californicus (Banks) is a ubiquitous species, which has been collected from numerous host plants throughout the world including *Musa* sp. in Venezuela (Freitez & Alvarado 1978), grapes, pears and peaches in Italy (Castagnoli 1984, 1988), forest trees such as *Cornus capitata* Wallich (Cornaceae), growing in Berkeley Hills, California and *Schinus terebinthifolius* Raddi (Anacardiaceae), growing in Oahu, Hawaii (Pemberton & Turner 1989). *Tydeus californicus* is abundant on citrus in the Mediterranean region, Bulgaria and Madeira Island (Gerson 1968), on apples, peaches, pears, citrus, and beans from Portugal (Carmona 1970; Ferreira & Carmona 1994, 1997), on sweet potatoes, egg plant, grape-vine, maize, beans and *Hibiscus rosa-sinensis* L. from Egypt (Osman 1974a, b; Wahab et al. 1974; Abo-Korah 1978-1979; Rizk et al. 1978-1979a, c), and on citrus from both Spain (García-Marí et al. 1985) and Australia (Smith et al. 1997).

Tydeus californicus was reported from leaves, branches and bark of citrus trees, as well as on perennial weeds under the trees in Israel (Gerson 1968). It was collected from bark of *Populus euphratica* Olivier, pine litter, leaves of *Pittosporum tobira* Thunberg, oleander litter, olive branches and branches of *Viburnum tinus* L. in Israel (Gerson 1968). It was also found on grapes in Taiwan (Tseng 1974). Fifty nine host plants, including ornamental trees and shrubs, were identified by Ripka and Kaźmierski (1998) for *T. californicus* in Hungary. *Tydeus californicus* was reported from eggplant, squash and beans in Egypt (Atalla et al. 1972).

Tydeus californicus was reported from *Malus domestica* Borhk, *P. domestica* L., *P. persica* (L.), *Prunus avium* (L.), *P. armeniaca* L., *Pyrus communis* L., *Eriobotrya*

japonica (Thunberg), *Cydonia oblonga* Miller, *Fragaria* sp., *Rubus* sp., *Prunus laurocerasus* L., *Medicago sativa* L., *V. tinus*., *Fraxinus sp.*, *Ulmus* sp., *Populus* sp., *Juglans regia* L., *Castanea sativa* Miller, *Olea europaea* L., *Tilia* sp., *Diospyros kaki* L., *Punica granatum* L., *Coffea* sp., *Ficus carica* L., *Vitis* sp., *Laurus nobilis* L., *Capsicum annuum* L., *Lycopersicon esculentum* L., *Cucurbita* sp., *Chrysanthemum coronarium* L.,and *Dahlia* sp. from Portugal (Carmona 1970).

Steven et al. (1997) reported the presence of *T. californicus*, along with *Tydeus caudatus* (Dugés) on kiwifruit leaves in Chile. They were often present in numbers exceeding 50 per leaf and comparable to those found on *Saissetia oleae* Bernard.

Lorryia formosa has been found associated with chayote squash (*Sechium edule* [Jacquin]), citrus, dahlia, pear, papaya, mango, *Cola acuminata* (Beauvois) and *Araucaria angustifolia* (Bertoloni) (Flechtmann 1973) in Brazil. In Portugal, it was reported from *Prunus domestica*, *P. persica*, *P. armeniaca*, *M. domestica*, *C. annuum* (Carmona 1970). Flechtmann et al. (1999) reported *L. formosa* from *Hibiscus* sp. collected in Guadeloupe, French Antilles.

Tydeus munsteri (Meyer & Ryke) was collected by Meyer and Rodrigues (1966) from cotton and also from citrus (Meyer 1998). Tydeidae comprised 44.37% of the sampled mite population on wild grapes in Central Florida (Walter & Denmark 1991). *Afrotydeus "munsteri"* sensu Baker 1970; *Tydeus kochi* group, *Tydeus* spp. *Orthotydeus* (junior synonym of *Tydeus*) sp. nr. *lindquisti* (Marshall) were the most abundant species found. Although densities often exceeded 200 per leaf, there was no indication of leaf damage. Body colors were pale or amber with no indication of chlorophyll present in their guts (Walter & Denmark 1991).

Tydeids Associated with Citrus

Tydeidae are found on citrus around the world. Twelve species were reported on citrus in Israel (Gerson 1971), six in Florida (Muma 1961) and 11 in Italy (García-Marí et al. 1985).

Rizk et al. (1978-1979c) reported *T. californicus* as a highly abundant predacious mite on citrus leaves and shoots in the Minia region of Egypt, especially between July and September. They also found *Pronematus ubiquitus* McGregor on leaves in low numbers. Baker and Wharton (1952) stated that *T. californicus* appeared to be predacious on the citrus bud mite, *Aceria sheldoni* (Ewing), in southern California. The role of *T. californicus* in nature is not fully understood. Fleschner and Arakawa (1952) considered this mite to be phytophagous since *T. californicus* was able to reproduce on avocado leaves free of fungus, insects or other mites. They also observed that young mites settled down to feed on the leaf surface immediately after hatching.

Thirteen species of tydeids, i.e., *Homeotydeus mali* (Oudemans), *Metalorryia magdalenae* (Gerson), *Orthotydeus foliorum* (Schrank), *T. caudatus*, *T. californicus*, *T. kochi* (Oudemans), *P. ubiquitus*, *Triophtydeus triophthalmus* (Oudemans), *Tydeus teresae* (Carmona), *T. australensis* Baker, *T. ferulus* (Baker), *T. reticulatus* Oudemans, and *L. formosa*, were found on citrus in the Mediterranean region (Vacante et al. 1988). *Tydeus californicus* was also found in Egypt, Israel, Italy, Spain and Portugal and *L. formosa* in Algeria, Italy, Libya, Morocco, Portugal and Spain (Vacante & Nucifora 1984; Vacante et al. 1988).

Pronematus ubiquitus was described by McGregor (1932) on citrus in California; however, its feeding habits were not determined. It was believed to feed on dead insects

or their eggs that were present on citrus foliage. McGregor (1956) found three species of tydeids associated with citrus in California: *T. californicus*, *Lorryia bakeri* McGregor (new species) and *P. ubiquitus*. *Tydeus californicus* according to McGregor (1956) was predacious on the citrus bud mite, *A. sheldoni*.

Muma (1961) found *Lorryia* sp., *Pronematus* sp. and *Tydeus* sp. on citrus in Florida. *Tydeus* spp. were abundant and included six to eight species that formed two distinct populations, one in the litter and one on the leaves and fruit. Populations on the leaves and fruit were uniformly distributed throughout the orchards. They peaked in the spring on leaves and on fruit in the summer. Higher densities were found in the central and west coast areas of Florida, and were slightly to distinctly more abundant on leaves than on fruit. During the spring, litter populations were much more abundant than those on leaves and fruit but in the other seasons they were equal or less abundant (Muma 1965). Among reported scavenger species, only *Tydeus* spp. were sufficiently abundant on leaves and fruit in several areas over seasons to be considered an alternate host for the common or abundant predators present, e.g. *Amblyseius peregrinus* (Muma) (Phytoseiidae) and *Agistemus* spp. (Stigmaeidae) (Muma 1961; Muma et al. 1971). These predacious mites were also found in association with spider mites. They were suspected of feeding primarily on phytophagous species, and survived on saprophagous species or vice versa. In either instance, prevalent scavenger species, *Tydeus* spp., must be considered to be potentially important (Muma 1965).

Tydeus californicus, *T. kochi*, *P. ubiquitus* and *Lorryia mali* Oudemans were collected from citrus in different geographical regions of Egypt (Zaher et al. 1970). They were placed in the list of predacious mites but no criteria were provided to support this.

Rizk et al. (1978-1979c) in a survey conducted on citrus and grape-vine in Egypt recorded *T. californicus* in high densities on both hosts, but considered that its feeding habits and economic importance needed clarification. Rizk et al. (1978-1979b) reported that *T. californicus* was the most abundant predatory mite species in orange and lemon ecosystems, especially during summer.

Rasmy (1969a) reported that *T. kochi* and *P. ubiquitus* were associated with *Eutetranychus orientalis* Klein on citrus in Egypt. *Tydeus californicus* was also found but not considered predacious. Rasmy (1969b) explained the negative effect of pesticides on the populations of phytophagous and predacious mites, since the chemicals used contributed to suppression of both groups of mites. *Pronematus ubiquitus* also displaced *Amblyseius* sp. during the second year of study as the most important predator species with densities of one per leaf, in an orchard free of pesticide applications.

Nine tydeid species were identified from material collected from 300 citrus orchards distributed in the provinces of Valencia, Murcia and Andalucía, Spain. Six were very common and their distribution was the same in all areas sampled throughout the year (García-Marí et al. 1985).

It was learned rather early that the mite *Pronematus ubiquitus* (*Tydeus ubiquitus* sp. nov.) was not phytophagous. Its food consisted of insects present on the foliage. The question as to whether this mite functions as a predator or as a scavenger has been difficult to determine. This ubiquitous mite confines its feeding chiefly to the dead bodies of insects and eggs, both commonly found associated with dead scales (McGregor 1932). *Lorryia turrialbensis* Baker was reported from *Citrus* sp. from the Philippines (Salviejo 1969) and Guadeloupe, French Antilles (Flechtmann et al. 1999).

Tydeids on Florida Citrus

Local diversity of tydeids is often high, with many species sharing the same types of hosts and subhabitats. For example, Muma (1975) collected *Tydeus gloveri* (Ashmead) from fruit, leaves and twigs of citrus; *Pseudolorryia mumai* (Baker), from leaves and bark of citrus; *Lorryia floridensis* Baker, *L. marcandrei* Baker, *Parapronematus acaciae* Baker, and *Triophtydeus* sp. from leaves; *Paralorryia shawi* (Baker), from bark; and *Lorryia* near *bedfordiensis* Baker, and *Tydeus tuttlei* Baker, from litter, all from citrus in Florida. Voucher specimens are stored in the Acarology collection, Division of Plant Industry, Florida Department of Agriculture and Consumer Services in Gainesville, Florida. Several of the slide preparations need to be remounted to conserve Muma's collection because the Hoyer's medium used for mounting the mites has crystallized.

Mites and Ground Cover Plants

Use of ground cover plants and their importance in sustaining populations of beneficial mites has been shown to be effective in encouraging increased levels of predacious mites, especially phytoseiids. There is no information about the relationship of tydeids and ground cover plants. The use of ground cover can greatly affect the status and complexity of arthropod population dynamics by altering the diversity and stability of the orchard ecosystem (Croft & Hull 1983; Alston 1994). Plant species on which multiple life stages of phytophagous mites were observed (i.e., eggs, immatures, and adults) were considered to be reproductive hosts for the mites, whereas plants on which only adults were found were not considered as hosts (Alston 1994).

Orchards with a total ground vegetation cover of 50% or more and less than 12% cover of reproductive host plants for mites had adequate predacious mite populations to maintain phytophagous mite densities in trees below economically damaging levels (Alston 1994). An increase in diversity and stability can be associated with an increase in density of natural enemies in orchards and a better balance established between these beneficials and the pests (Alston 1994). It appears that the type of ground cover plants grown and their density may be important to the management of pest and beneficial arthropods, which relates to the biological control agents occurring in a particular ecosystem (Alston 1994). The use of orchard ground cover manipulation as an integrated mite management tactic holds great potential.

Withholding herbicide applications in the spring to allow ground cover to grow beneath apple trees did not result in greater numbers of *Neoseiulus fallacis* (Garman) in trees during the summer compared with plots where herbicides were applied and ground cover was greatly reduced (Nyrop et al. 1994). Some species of beneficial arthropods establish their ecological niches in the tree and the flow of organisms from ground cover plants to the tree and vice versa is unnecessary to maintain a dynamic interaction among different species. Similar situations may occur in other perennial ecosystems like citrus, where some growers leave the ground cover crops growing underneath the citrus trees while others follow a strict weed control program.

Feeding Behavior

Tydeidae feed largely on fungi and decaying material, although some are known to be predacious on insects and mites and a few have been reported to damage plants

(Jeppson et al. 1975; Pemberton & Turner 1989). Algae and pollen are known sources of food for tydeid mites but some species are facultative predators and others can be important biocontrol agents of plant-parasitic mites (Walter & Proctor 1999). Because of the many possible food habits of the Tydeidae, it is necessary to critically evaluate each important species within a particular ecosystem (Hessein & Perring 1986).

The feeding behavior of tydeid mites is highly diverse, and species have been identified as being predacious, e.g., *Tydeus coccophagus* Ewing, on oyster shell scale, *Lepidosaphes ulmi* (L.) (Ewing 1911; Samarasinghe & Leroux 1966), *T. californicus* on the citrus bud mite, *A. sheldoni* (Baker & Wharton 1952), and on *Tetranychus arabicus* Attiah (Atalla et al. 1972); *Lorryia ferulus* Baker on *Tetranychus urticae* Koch eggs (Brickhill 1958); *Lorryia* sp. on oyster shell scale (Samarasinghe & Leroux 1966); *Pronematus* sp. on *Brevipalpus phoenicis* (Geijskes) (Borthakur 1981), and *H. anconai* on eggs of the Pacific spider mite *Tetranychus pacificus* McGregor and the Willamette spider mite *Eotetranychus willamettei* Ewing (Knop & Hoy 1983 a, b, c); on the tomato russet mite, *Aculops lycopersici* Massee (Hessein & Perring 1986), and on *Brevipalpus lewisi* McGregor (Hessein & Perring 1988a). Some of the most important reports of significant levels of nematophagy involve tydeid mites often thought to be primarily fungivorous (Walter & Proctor 1999). Santos and Whitford (1981) and Santos et al. (1981) determined that tydeid mites play a key role in the control of rhabditid nematodes, facilitating the decomposition of soils, since these mites prevent predation on soil bacteria by the nematodes. Other tydeid mites have been reported as phytophagous, such as *T. californicus* on avocado leaves (Fleschner & Arakawa 1952), and *L. formosa* on citrus (Smirnoff 1957; Inserra 1967; Flechtmann 1973), while some species are

apparently fungivorous, such as *P. acaciae* on *Penicillium digitatum* Saccardo and *Colletotrichum gloeosporioides* Penzig (McCoy et al. 1969); *L. formosa* on citrus sooty mold (Mendel & Gerson 1982), and *T. lambi* on *Uncinula necator* (Schweinitz) (English-Loeb et al. 1999). Honeydew feeders such as *L. formosa* on *S. oleae* (Smirnoff 1957; Inserra 1967), *T. californicus* on the rosy apple aphid, *Dysaphis plantaginea* (Passerini) (Bayan 1986), and *L. ferulus* on hemispherical scale, *Saissetia hemisphaerica* Targioni (Brickhill 1958) have been reported along with scavengers, such as *P. ubiquitus* and *Triophtydeus* sp. feeding on dead insects and mite remains (García-Marí et al. 1991).

In experiments conducted by Zaher and Shehata (1963), *T. californicus* larvae were offered *Oligonychus mangiferus* Rahman & Sapra larvae, but died within four days. Then, larvae of the spider mite were supplied to *T. californicus* adults but the latter remained alive for only 6 days. A third experiment dealt with larvae of *T. californicus* and eggs of *O. mangiferae*, but they did not feed on the spider mite's eggs. Finally, *T. californicus* larvae were placed on sweet potato cuttings and the tydeids completed their life cycle, giving rise to adults which, in turn, produced other larvae. Based on their results, the investigators concluded that *T. californicus* was a plant feeder and not a predator. However, these authors failed to look at surface contaminants.

Fungi as a food source for tydeids

The conidia produced by numerous fungi have been reported as a food source for some species of phytoseiid mites, and this type of food appears to be important for some species of tydeids too (English-Loeb et al. 1999). The conidia of the powdery mildew *Erysiphe orontii* Castagne can supply mites with water and nutrients necessary for their normal development (Zemek & Prenerová 1997).

Zemek and Prenerová (1997), working with phytoseiids, found that they pierced the conidium of the powdery mildew with their mouthparts followed by the motion of liquids being transferred into the gut. This was visible through their translucent bodies. Three powdery mildew species, i.e., *Erysiphe polygoni* de Candolle, *E. oronti*, and *Oidium fragariae* Harz were offered separately to at least ten *Typhlodromus pyri* Scheuten females. Two species of mildews, *E. orontii* and *O. fragariae*, provided sufficient food not only for completion of development but also for egg production although the oviposition rate was very low. Thus, *E. orontii* could be considered as an alternative food based on Overmeer's (1985) definition because mites not only could survive and develop. They also were capable of reproducing when feeding on the powdery mildew (Zemek & Prenerová 1997). Macroscopic examination has proved the presence of spores within the digestive tracts of the mites (Zemek & Prenerová 1997). This type of observation was proved by English-Loeb et al. (1999) when they studied tydeid feeding on the powdery mildew *U. necator* on grapes in New York. They demonstrated that *T. lambi* fed on mycelia of the fungus and controlled the pathogen. Additional studies by Norton et al. (2000) corroborated these results. McCoy et al. (1969) found that *P. acaciae* was able to produce multiple generations when fed two common leaf-inhabiting fungi, *P. digitatum* and *C. gloeosporioides*. Childers and Enns (1975) reported clusters of a large *Tydeus* sp. associated with minute black fruiting bodies of a fungus, on spurs of 'Red Delicious' apple trees in Missouri. All of the tydeid stages were found together under dead bark at the tip of the cut twigs. Feeding was not reported, even though the mites had black-colored guts. Hessein and Perring (1986) observed that the predacious tydeid *H. anconai* was able to feed on *Cladosporium*

cladosporioides Fries. They concluded that fungi as a food source were not conducive to high levels of *H. anconai* reproduction, since eggs were rarely noticed throughout the 30-day observational period.

Honeydew as a food source

The Tydeinae and Triophtydeinae were observed to feed on honeydew but reportedly could occasionally feed on plants, e.g. citrus and avocado by *T. californicus* (Fleschner & Arakawa 1952) or function as predators of other mites such as Tetranychidae (mostly on eggs) and Eriophyidae (all stages except adults) (Fleschner & Arakawa 1952; Brickhill 1958; Schruft 1972; Wahab et al. 1974; Karg 1975; André, 1986).

According to Bayan (1984), the feeding habits of *T. californicus* on apple in Lebanon varied depending on the stage of the mite. Larvae and protonymphs would feed primarily on honeydew excreted by the rosy apple aphid, *D. plantaginea*, while deutonymphs, tritonymphs and adults would feed and develop on apple leaves free from aphids. Bayan collected apple leaves and twigs from different regions of Lebanon but he did not explain the methods used to determine the feeding habits of *T. californicus*. McGregor (1956) and Krantz (1986) stated that *P. ubiquitus* was omnivorous, feeding on honeydew, fungi, and dead arthropods.

Steven et al. (1997) stated that the high numbers of *T. californicus* and *T. caudatus* found on kiwifruit leaves, were a reflection of the high densities of *S. oleae*, on which the tydeids fed, as well as fungal development on the honeydew.

Predatory nature of tydeids

The most characteristic acarine inhabitants of leaf and forest types are tydeid

mites (Walter & Proctor 1999). Many tydeids are suspected of being opportunistic predators, e.g., species of *Tydeus*, *Orthotydeus* (junior synonym with *Tydeus*), and *Pronematus*, especially of eriophyoid mites (Walter & Proctor 1999). These tydeids tend to be pale to apricot in color. Species in other genera, however, often have deep greenish hues, presumably from feeding on algae and lichens. Herbivory is suspected in some foliar tydeids but there is no convincing evidence that any tydeid mites are plant parasites (Walter & Proctor 1999).

The Oriental mite, *E. orientalis,* is an important pest on citrus in the Middle East, Asia, Australia, and Africa, causing considerable feeding damage to leaves, twigs and fruit of host plants (Gupta et al. 1971; Sadana & Kanta 1971; Smith et al. 1997). The infested leaves become chlorotic, twigs and branches dry up, and the leaves and fruit drop prematurely. Since this is a serious pest in a broad citrus area, many researchers are looking for control methods. One possible way is biological control. A *Pronematus* sp. has been observed feeding on eggs, larvae and nymphs of *E. orientalis* on citrus in India (Sadana & Kanta 1971). Gupta et al. (1971) stated that the most important predator of *E. orientalis* was a *Pronematus* sp. found in large numbers on citrus trees attacked by the spider mite. These predatory mites were very active and fed on all stages of *E. orientalis,* especially the eggs. The whitish natural color of this mite turned pinkish and light brownish when fully fed.

Borthakur (1981) observed a *Pronematus* sp. feeding on the scarlet mite, *B. phoenicis* with as many as 5 false spider mites consumed per hour on tea in India. Old infested leaves with scarlet mites are normally avoided by *Pronematus* sp. *Pronematus* deutonymphs and adults could be reared on tea leaves in the laboratory without providing

scarlet mites as food. According to Borthakur (1981), this suggests that this species is phytophagous. Female predators oviposited even in absence of prey. However, larvae and protonymphs could not be reared in the absence of *B. phoenicis*. It appears that the predator needs extra protein for development during early stages and, like other predacious mites, can live without animal protein during the later stages of development (Borthakur 1981).

Hessein and Perring (1986) conducted several experiments dealing with the feeding behavior of *H. anconai* on tomatoes in California. This species is a known predator of the tomato russet mite (TRM), *A. lycopersici*. They found significant differences between TRM numbers on leaflets with *H. anconai* present than those without. The leaflets on which *H. anconai* occurred, remained healthy and green, while those without the predator, turned yellow and dried out. Their findings confirmed predation by a tydeid on an economically important eriophyid pest. They concluded that predation and phytophagy are considered to be important for the survival, reproduction and population growth of this species. Carmona (1970) reported "the remains of TRM in the gut" of *P. ubiquitus* on tomato in Portugal.

Pollen: Knop and Hoy (1983a) concluded that pollen was necessary for egg production in their studies with *H. anconai* on grapes in California. Hessein and Perring (1986) evaluated three types of pollen: bottle brush, *Callistemon citrinus* (Curtis), ice plant, *Carpobrotus chilensis* (Molina), and cattail, *Typha latifolia* (L.). They found that eggs were produced continually when *H. anconai* fed on pollen only, on TRM only, or when a combination of these food sources was provided while confined on tomato leaves. Pollen likely served as a supplemental nutrient source which, along with predation, is considered

to be important for the survival, reproduction and population growth of this species (Hessein & Perring 1986).

Tydeids as alternative prey

Homeopronematus anconai and *P. ubiquitus* served as alternate prey to the predatory mite, *Galendromus occidentalis* (Nesbitt) (Phytoseiidae), late in the season and in the absence of spider mites in studies conducted in California vineyards (Flaherty & Hoy 1971). This late-season predator and alternate prey relationship is necessary to stabilize the Pacific mite, *T. pacificus* populations and maintain a balance in San Joaquin Valley vineyards (Flaherty & Hoy 1971).

Calvert and Huffaker (1974) demonstrated that *Pronematus* spp. served as primary prey in the absence of phytophagous mite species and were capable of supporting a relatively large, well distributed *G. occidentalis* population for an entire growing season. Their data support the view held by Flaherty and Huffaker (1970) that tydeids may be an important alternate prey during the late autumn period when Pacific mites are scarce.

T. pyri is found in apple orchards and controls phytophagous mites including the European red mite, *Panonychus ulmi* (Koch) (Tetranychidae) (Calis et al. 1988). The ability of *T. pyri* to complete its development and reproduce on *T. caudatus* may contribute to its effectiveness as a biological control agent (Calis et al. 1988).

Karg (1990) used the term "indifferent species" for those species which serve as secondary prey for predatory mites when their principal food sources become scarce. Some of the most important species that serve as alternate prey for phytoseiids in apples reportedly include the Tydeidae and Eriophyidae. Several species in the genera *Tydeus*

and *Lorryia*, as well as *Paralorryia* and *P. ubiquitus,* were found by Karg (1990) as alternate prey for phytoseiids.

Tydeids as contaminants

Some blueberry crops have been contaminated by tydeid mites (Baker 1983) and Tomkins and Koller (1985) reported contamination in highbush blueberries in New Zealand, especially on unsprayed plants. They found that willow weed (*Polygonum persicaria* L.), an alternative tydeid mite host growing beneath blueberry bushes, led to serious fruit contamination by tydeid mites (Tomkins & Koller 1985). Tomkins et al. (1997) also found that *T. caudatus* and *T. californicus* occasionally contaminated persimmon fruit. Jones et al. (1996) reported that a hot water treatment is an effective method in controlling *T. californicus*, a contaminant of apricots in New Zealand.

Biological and ecological knowledge on tydeid mites on citrus will serve as a guide to better understand their role in the citrus system, and will help in the integration of the major components for establishing an Integrated Pest Management (IPM) on Florida citrus.

CHAPTER 3
TYDEIDAE ASSOCIATED WITH CITRUS IN FLORIDA, TEXAS, LOUISIANA AND SELECTED COUNTRIES

Introduction

Tydeidae have been collected from citrus throughout the world by numerous authors. For instance, Banks (1904) collected *T. californicus* from orange leaves in California. Quayle (1912) found *T. californicus* in high numbers on citrus trees in California but neither indicated when they occurred nor the mite densities present. *Pronematus ubiquitus* was also found on citrus in California by McGregor (1932). McGregor (1956) later found *T. californicus* and *L. bakeri* along with *P. ubiquitus* on citrus in southern California.

Gerson (1971) reported 12 tydeid species from citrus in Israel and García-Marí et al. (1985) collected 9 species from Spanish citrus. Benfatto (1980) reported *T. foliorum* and *L. formosa* as the most common on citrus in Sicily. Vacante and Nucifora (1984-1985) reported 11 species of Tydeidae on citrus in Italy.

Vacante et al. (1988) listed the species of Acari associated with citrus and identified 13 tydeid species distributed in 8 Mediterranean countries. *Tydeus californicus* was found in Egypt, Israel, Italy, Spain and Portugal and *L. formosa* in Algeria, Italy, Libya, Morocco, Portugal and Spain (Vacante et al. 1988), and both tydeid species were previously reported from Italy (Vacante & Nucifora 1984-1985).

Tydeus californicus was reported as highly abundant on citrus leaves and shoots in the Minia region of Egypt (Rizk et al. 1978-1979c). Carmona (1970) reported *L. formosa* and *T. californicus* on orange trees from September to May in Faro, Tavira and Setúbal in Portugal. Soares-Chaves (1995) reported the presence of *L. formosa* in high densities on citrus in the Algarve region of southern Portugal during winter, without indicating damage to the trees. Baker (1968a) reported that the records of *L. formosa* in the U.S. National Museum collection were from samples collected in Spain, France, Argentina, Brazil, Chile, and Uruguay from citrus, avocado from Ecuador and *Gardenia* sp. from Mexico. *Tydeus californicus, L. formosa,* and *P. ubiquitus* appear to be the three most common species found in the Old and New worlds associated with citrus.

García-Marí et al. (1985) found that *L. formosa* was the dominant species on citrus in Spain, especially in autumn and spring, whereas *T. californicus* was second in importance, being more abundant between May and August. *Lorryia formosa* was more abundant in October and November, while the lowest densities were observed between May and July.

The objective of this study was to identify the Tydeidae associated with citrus in Florida, Texas, Louisiana and selected countries.

Materials and Methods

Tydeid identification from a preliminary citrus survey (1986-1987).

In a preliminary study, tydeid specimens were identified from leaf and fruit samples taken directly from citrus trees and washed in a 5-liter bucket containing about 250 ml of 70% ethanol. The ethanol from each sample was poured into a labeled glass

jar, and returned to the laboratory for processing. These studies were conducted during 1986 and 1987 in 20 mature orchards in 11 counties throughout Florida. The orchards were sampled qualitatively as follows: Brevard Co.: Reece (4 ha of grapefruit), in Merritt Island; Collier Co.: Berry (10 ha of grapefruit), about 13 km northwest of Immokalee, and Price (8 ha of 'Hamlin' orange), 24 km south of Immokalee; DeSoto Co.: Ft. Ogden (6 ha of 'Marsh' grapefruit), Sunny South Farms, in Ft. Ogden; Hardee Co.: Lafon (6 ha of 'Duncan' grapefruit), in Bowling Green; Hendry Co.: Duda (8 ha of 'Marsh' grapefruit) in Felda; Highlands Co.: Kahn (4 ha of 'Valencia' orange) and Smoak (4 ha of 'Valencia' orange), 16 km south of Lake Placid; Hillsborough Co.: Herring (2 ha of 'Hamlin' orange), in Ft. Lonesome; Lee Co.: Brooks/Corkscrew (40 ha of 'Tahiti' lime), 3 km north of Corkscrew Swamp, and Frank Green (2.5 ha of 'Valencia' orange), 6 km north of Alva; Orange Co.: Shirard (24 ha of 'Hamlin' orange), 16 km west of Orlando; Polk Co.: Albritton (4 ha of 'Hamlin' orange), in Frostproof vicinity, Church (4 ha of grapefruit), in Brewster, Durrence (4 ha of 'Hamlin' orange), 13 km west of Frostproof, Fulton (4 ha of 'Hamlin' orange), in Frostproof; St. Lucie Co.: Coca Cola (8 ha of 'Valencia' orange), 16 km west of Ft. Pierce, and Girl Scout (2 ha of 'Valencia' orange), 8 km west of Ft. Pierce.

Tydeid mites identified from seven selected orchards (1995-1996).

Seven citrus orchards in three counties in central and south central Florida were sampled monthly from January 1995 to January 1996. Tydeids were collected from 100 inner and outer leaves, 10 inner and outer twigs, 25 immature fruit, single mature fruit, 100 open flowers (when available), and brushings from the trunk. These sites were: Trask

(4 ha of 'Hamlin' orange) located in the vicinity of Highland City on CR 540A; Yarborough (4 ha of 'Hamlin'orange) located in Highland City on Yarborough Lane, and Pollard (4 ha of 'Duncan' and 'Marsh' grapefruit) in Highland City on Tillery Rd., the three in Polk Co.; Hart I (4 ha of 'Ambersweet' orange), and Hart II (4 ha of navel orange), both in the vicinity of Mascotte, in Lake Co.; and Mixon I (4 ha of 'Marsh' grapefruit) and Mixon II (4 ha of 'Valencia' orange), both orchards located in southeastern Arcadia, in DeSoto Co. Pest control within each of these mature orchards varied from modified to non-pesticide sprayed programs (Table 3-1).

Each sample was immediately washed in a 5-liter bucket containing about 250 ml of 80% ethanol. The ethanol from each sample was poured into a labeled glass jar, and returned to the laboratory for processing.

Tydeid mites identified from other orchards throughout Florida (1997-1999).

Material consisting mostly of leaves, fruit, twigs and, occasionally from unidentified aerial plants associated with citrus, was collected from numerous orchards in several counties throughout Florida. The procedures of collecting, processing, and identifying the material were exactly as those described above. The orchards sampled were: Dade Co.: Quail Roost (4 ha of 'Tahiti' lime), in Homestead, and the citrus collection in the Tropical Research and Education Center –TREC- (2 ha of 'Tahiti' limes, and mixed grapefruit, pummelo, orange and lemon varieties), in Homestead; DeSoto Co.: Ft. Ogden (6 ha of 'Pineapple' oranges), Sunny South Farms, in Ft. Ogden, Joshua orchard (4 ha of 'Hamlin' oranges), Orange-Co, in Arcadia, and LM Stewart (1 ha of organically grown 'Valencia' oranges associated with vegetables), in Arcadia; Hardee

Co.: Lafon (6 ha of 'Duncan' grapefruit), in Bowling Green, Ona (1 ha of volunteer citrus), vicinity of Wauchula; Hendry Co.: CPI (10 ha of red grapefruit), vicinity of Immokalee, and Duda (8 ha of navel orange), in Felda; Highlands Co.: Smoak (4 ha of 'Valencia' oranges), 16 km south of Lake Placid; Lake Co.: Faryna (4 ha of 'Hamlin' oranges), vicinity of Montverde; Manatee Co.: unidentified orchard (10 ha of 'Marsh' and red grapefruit), 38 km west of Arcadia; Martin Co.: Becker Groves (5 ha of 'Marsh' grapefruit), Hobe Sound vicinity; Lee Co.: Frank Green (2.5 ha of 'Valencia' oranges), 6 km north of Alva, Jay R orchard (0.5 ha of volunteer citrus, shaded by pine trees and cabbage palm), 31 South Persimmon Ridge; St. Lucie Co.: Driscoll Citrus Service Inc. (4 ha of 'Marsh' grapefruit), across from Kraft Gardens, vicinity of Ft. Pierce, Dunn orchard (1 ha of 'Marsh' grapefruit), Picos Rd., vicinity of Ft. Pierce, Girl Scout (2 ha of grapefruit), 8 km west of Ft. Pierce; orchard next to Girl Scout (2 ha of 'Valencia' oranges), 8 km west of Ft. Pierce, and Ray Heffner (unidentified grapefruit variety), vicinity of Ft. Pierce.

Tydeid mites identified from citrus orchards located in Texas and Louisiana (1999).

Tydeid specimens collected from qualitative citrus leaf and fruit samples in Texas were washed in a 5-liter bucket containing about 250 ml of 80% ethanol. The ethanol from each sample was poured into a labeled glass jar, and returned to the laboratory for processing. The material was sorted and placed in labeled vials containing 80% ethanol, and it was collected separately from the following orchards located in Hidalgo Co.: Texas A&M West Research Farm, about 15 km northwest of Mission (10 twigs, 50 inner

Table 3-1. Pesticide programs for seven citrus orchards sampled for Tydeidae in Florida during 1995-1996.

ORCHARD	HERBICIDES	INSECTICIDES/ ACARICIDES	FUNGICIDES
Trask Polk Co. ('Hamlin' orange)	NOT APPLIED SINCE 1995	NOT APPLIED SINCE 1995	NOT APPLIED SINCE 1995
Yarborough Polk Co. ('Hamlin' orange)	glyphosate 1994, 1995	Petroleum oil + (Mn, Zn) (1994)	Copper (1994)
Pollard Polk Co. ('Duncan'/ 'Marsh' grapefruit)	NO	NO	NO
Hart I Lake Co. ('Ambersweet' orange)	glyphosate 1993, 1995	ethion + petroleum oil (summer 1993) fenbutatin oxide (spring 1993) propargite (fall 1993 and 1994)	NO
Hart II Lake Co. (navel orange)	NOT APPLIED SINCE 1992	NOT APPLIED SINCE 1992	NOT APPLIED SINCE 1992
Mixon I DeSoto Co. ('Marsh' grapefruit)	glyphosate, norflurazon, simazine, sethoxydim, diuron	NO	NO
Mixon II DeSoto Co. ('Valencia' orange)	glyphosate, norflurazon, simazine, sethoxydim, diuron	NO	NO

leaves, 50 outer leaves, 20 fruit, of red grapefruit); Texas A&M Citrus Center, South Research Farm, near Weslaco (20 inner twigs of red grapefruit); Eberhard orchard on Minnesota Road, about 7 km northwest of Mission (50 inner leaves, 50 outer leaves, 20 fruit, 10 inner twigs, of navel orange); 907 orchard, on Farm Rd. to Market Rd. (FM 907) between Pharr and San Juan (20 fruit, 10 inner twigs, 50 inner leaves); Thompson orchard, just north of Donna (20 fruit, 50 outer leaves, 10 inner twigs, 50 inner leaves of navel orange and grapefruit), Pharr orchard, in Pharr (10 twigs, 50 inner leaves, 50 outer leaves, 20 fruit). These materials were collected on 29 January 1999.

Material from Louisiana was collected separately and in the same manner as described from Texas in the following orchards located in Plaquemines Parish: Matt Rinataza, near Belle Chasse (50 inner leaves, 50 outer leaves, 20 fruit, 10 twigs, of navel orange and mandarin); Joe Rinataza, near Jesuit Bend (50 inner leaves, 50 outer leaves, 20 fruit, 10 twigs, of navel orange and mandarin); J. Sisk, near West Pointe a La Hache (fruit, inner leaves, twigs, outer leaves of mandarin and navel orange); Lester, on the west side of the Mississippi River, near the community of Stella (fruit of navel orange); Jesuit Bend, on Jesuit Bend (10 twigs, fruit, and leaves of navel orange); Eppley, on the west side of the Mississippi River (fruit of tangerine). All collections were taken on 1 February 1999.

Tydeidae collected from other citrus producing countries (1997-1999).

The procedures used to collect the qualitative samples overseas were similar to those followed in Florida, Texas and Louisiana. All the samples were collected separately, taken to the laboratory or hotel room for sorting the mite species into vials

containing 80% ethanol. The vials were later transported to the laboratory in Lake Alfred, processed and identified.

1) Bahamas:

- Great Abaco Island. Material collected from a commercial orchard of white grapefruit on 3 January 1997.

2) Brazil:

- São Paulo, Municipio Registro, Boavista orchard (fruit, leaves, twigs of 'Mishirika Rio' tangerines) on 2 June 1998.
- São Paulo , Municipio Pariquera Açu, Pariquera Açu Experiment Station, Instituto Agronômico de Campinas (IAC) (fruit, leaves, twigs of sweet orange and lemon) on 2 June 1998.
- São Paulo, Cordeirópolis, Centro de Citricultura Sylvio Moreira (fruit, leaves, twigs of mandarin, Mimosa tree wood) on 3 June 1998.
- São Paulo, Piracicaba, University of São Paulo (ESALQ), Citrus variety collection including leaves from 'Baía', 'Hamlin', 'Lima' and other orange varieties on 5 June 1998.

3) Dominican Republic:

-Hato Mayor vicinity (leaves, dead twigs, fruit). Collecting was conducted in the following orchards: CCE-Juan Jiménez fields Nos. 53, 251 and 259 ('Valencia' orange); JR-Frank (Manchado), JR-Frank (Cholito); Cercado Barina, Cercado

Cabrera, AgroDelta No. 33 (grapefruit). Material collected on 22 and 23 March 1999.

4) Italy:

-Florence, Medician Villa of Castello (via di Castello, n. 40) (leaves from potted citrus species, i.e., *C. aurantifolia* (Christmann) Swingle, *C. aurantium* L., *C. bergamia* Risso & Poiteau, *C. deliciosa* Tenore, *C. grandis* (L.), *C. limon* (L.), *C. medica* L., *C. myrtifolia* Rafinesque, *C. paradisi* Macfady, *C. sinensis* (L.) and some other old unidentified citrus varieties) on 18 May 1999.

5) Morocco:

-Mimosa-Salé (leaves, fruitlets, fruit). Collected from lemon in the greenhouse and grapefruit in the field on 8 May 1999.

-Larache, vicinity, Sodea orchard (leaves from 'Clementina' mandarin) on 8 May 1999.

-Kenitra Province, Mechrara Belksiri, Sodea orchard (leaves from 'Clementina' mandarin) on 8 May 1999.

-Rabat, Marjane Market (leaves from sour orange on the road next to the market) on 9 May 1999.

-Rabat, Unité de Contrôle des Plantes Domains Agricoles (leaves of grapefruit) on 9 May 1999.

-Agadir Province, Tikiovine (fruit, leaves from 'Valencia' orange and lemon) on 10 May 1999.

-Agadir Province, Temsia, (leaves, fruit of 'Valencia' and sour orange) on 10 May 1999.

-Taroudant Province, Ain Chaîb (leaves of 'Valencia' and sour orange) on 10 May 1999.

-Taroudant Province, El Boura Domaine (leaves of 'Valencia' orange and a ground cover vine –*Ipomoea* sp.) on 11 May 1999.

-Taroudant Province, Ouled Aissa Domaine (leaves of 'Valencia' orange) on 11 May 1999.

6) Portugal:

-Faro, Campina de Faro, Conceicão de Faro, Quinta da Nora (leaves of 'Valencia-Don João' orange) on 24 May 1999.

-Olhão, Moncarapacho, Areias, Moinho (leaves of 'Valencia' and 'Baía' oranges) on 24 May 1999.

-Olhão, Moncarapacho, Pereirinhas, Horta do Lameiro (leaves of 'Situbalense' and 'Clementina' tangerines) on 24 May 1999.

-Tavira, Fundo, Luz de Tavira (leaves of 'Valencia' orange) on 24 May 1999.

-Tavira, Centro de Experimentacão Agrária de Tavira, Pomar Don João (leaves of 'Valencia' orange late) on 24 May 1999.

-Silves, Ferrarias, Algos, Quinta do Pavão (leaves of 'Valencia' orange late) on 25 May 1999.

-Silves, Lapa, Ferrarias, Algos, Quinta do Calado (leaves of 'Valencia' orange late) on 25 May 1999.

-Silves, Afonso Vaz, Algos (leaves of 'Valencia' orange late) on 25 May 1999.

-Silves, Vale da Vila, Antena (leaves of 'Valencia' orange late) on 25 May 1999.

-Silves, Torre e Cercas (next to the road), (leaves of 'Clementina' mandarin) on 25 May 1999.

-Silves, Baixa de Silves (leaves of 'Valencia' orange late) on 25 May 1999.

7) Spain:

-Valencia Province, Picassent, Tres Barrancos (leaves of 'Washington' navel orange in an abandoned orchard) on 13 May 1999.

-Valencia Province, Sueca town (leaves of 'Salustiana' orange) on 13 May 1999.

-Valencia Province, Riola town (leaves of 'Newhall' orange) on 13 May 1999.

-Alicante Province, Pego town, Racó Marques (leaves of 'Washington' navel orange) on 19 May 1999.

-Alicante Province, Pego town, Peña Roja (leaves of 'Washington' navel orange) on 19 May 1999.

-Valencia Province, city of Valencia, Gran Vía, Ramón y Cajal, (leaves of sour orange) on 20 May 1999.

-Valencia Province, Godella town, Domus College (leaves of sour orange) on 20 May 1999.

-Valencia Province, city of Valencia, behind C.M. Albilat building, Lardi buildings (leaves of sour orange) on 20 May 1999.

-Valencia Province, Godella town, Tramuntana street (leaves of sour orange) on 20 May 1999.

-Valencia Province, city of Valencia, street adjacent to streetcar platform (leaves of sour orange) on 20 May 1999.

-Valencia Province, Rocafort, Burjassot street (leaves of sour orange) on 21 May 1999.

Tydeids were separated, counted and subsamples were slide-mounted in Hoyer's medium (Krantz 1986) and identified with a phase contrast microscope using available keys (Baker 1965, 1968a, b, c, 1970; André 1980; Kaźmierski 1998b). A key to the species of Tydeidae collected during these surveys was included. Voucher specimens of all tydeid species were deposited at four locations: the Citrus Research and Education Center, University of Florida, Lake Alfred, Florida, USA; the Florida State Collection of Arthropods, Florida Department of Agriculture and Consumer Services, Division of Plant Industry, Gainesville, Florida; the USDA, Systematic Entomology Laboratory, Beltsville, Maryland, USA; and in the Laboratory of Acarology, Faculty of Agronomy, University of Costa Rica, San José, Costa Rica.

Results

Tydeid identification from a preliminary citrus survey (1986-1987).

The tydeid fauna associated with Florida citrus between 1986 and 1987 is listed in Table 3-2. Four species of Tydeidae, *L. formosa*, *P. mumai*, *T. gloveri*, and *T. munsteri* were found in 20 orchards located in 11 counties.

Notes on the species collected

A qualitative survey was completed to determine the tydeid composition in several orchards located in different citrus-producing counties in Florida. Tydeids were recovered from both leaves and fruit. Bloom sets were also collected from one of the orchards. *Lorryia formosa* was recovered from leaves in 5 orchards and from fruit in only one. *Pseudolorryia mumai* was found on leaves, fruit and bloom sets, from material collected in 9 orchards. *Tydeus gloveri* was collected during most sample dates, and was the most common tydeid species found in this survey. It was recovered from leaves, fruit and bloom sets in 14 orchards located in 9 counties. The second most abundant species found was *T. munsteri*, which was collected on 18 sampling dates in 11 orchards distributed in 8 counties. *Tydeus munsteri* was also collected from fruit, leaves and bloom sets.

Tydeid mites identified from seven selected orchards (1995-1996).

The tydeid fauna associated with citrus was collected from 7 orchards in 3 Florida counties between 1995 and 1996 and listed in Table 3-3. Nine Tydeidae species, i.e., *L. formosa*, *P. shawi*, *P. mumai*, *T. californicus*, *T. gloveri*, *T. munsteri*, *Apopronematus* sp., *Metapronematus* sp., and *P. acaciae* were found.

Table 3-2. Survey of Tydeidae in different orchards throughout Florida, 1986-1987.

ORCHARD	CULTIVAR	PLANT HABITAT	*L. formosa*	*P. mumai*	*T. gloveri*	*T. munsteri*
Brevard Co.						
Reece	grapefruit	young fruit		Oct87		Oct87
	grapefruit	leaves				Oct87
Collier Co.						
Berry	grapefruit	mature fruit			Nov87	
Price	'Valencia' orange	mature fruit				Nov87
	'Valencia'	leaves				Nov87
	'Hamlin' orange	leaves		Jun86	Feb86	
	'Hamlin'	leaves		Apr87	Apr87	
	'Valencia'	leaves		Oct87		
DeSoto Co.						
Ft. Ogden	'Marsh' grapefruit	young fruit		Nov87	Nov87	Nov87
	'Pineapple' orange	leaves	Jul86, Nov87		Nov87	
	'Pineapple'	mature fruit			Oct87	
Hardee Co.						
Lafon	'Duncan' grapefruit	leaves	Dec87		Dec87	Dec87
Hendry Co.						
Duda	grapefruit	young fruit			Oct87	
Highlands Co.						
Kahn	'Hamlin'	young fruit		Oct87		
Smoak	'Valencia'	leaves	Oct87			

Table 3-2- continued

ORCHARD	CULTIVAR	PLANT HABITAT	*L. formosa*	*P. mumai*	*T. gloveri*	*T. munsteri*
Hillsborough Co.						
Herring	grapefruit	leaves				Oct87
	grapefruit	leaves			Oct87	Oct87
	'Hamlin'	leaves				Oct87
Lee Co.						
Brooks/Corkscrew		bloom sets		Nov87	Nov87	Nov87
Frank Green	'Hamlin'	leaves	Oct87		Oct87	Oct87
	'Valencia'	leaves			Oct87	
Orange Co.						
Shirard	'Valencia'	leaves			Oct87	
Polk Co.						
Albritton	'Hamlin'	young flush				Nov87
	'Hamlin'	leaves	Mar87	Dec87		Dec87
Church	'Hamlin'	leaves			Oct87, Dec87	Oct87, Dec87
Durrence	'Valencia'	leaves			Oct87	
Fulton	'Hamlin'	young fruit		Oct87		
	'Hamlin'	leaves		Oct87		
Lambert	'Hamlin'	young fruit			Oct87	
Mac Sharpe	'Pineapple'	young fruit		Oct87		
		leaves				Nov87
St. Lucie Co.						
Coca Cola	'Valencia'	mature fruit			Oct87	
Girl Scout	'Valencia'	young fruit	Oct87		Oct87	Oct87
	'Valencia'	young flush			Oct87	Oct87

Notes on the species collected

A qualitative survey was completed to determine the tydeid fauna in different citrus habitats throughout the year. *Lorryia formosa* was found in all 7 orchards in high numbers, mostly on leaves, but also on fruit, twigs, trunk brushings, and flowers. *Pseudolorryia mumai* was also found in all orchards and in all habitats sampled except flowers.

Tydeus californicus was collected from leaves in 2 orchards and *T. gloveri* was collected from 6 orchards from all habitats except trunk brushings. *Tydeus munsteri* was found in all habitats except twigs in 4 of the 7 orchards.

Paralorryia shawi and *Apopronematus* sp. were collected exclusively from trunk brushings. *Paralorryia shawi* was found in 4 of the 7 orchards on tree trunks, whereas *Apopronematus* sp. was found in 3 orchards on tree trunks too. *Metapronematus* sp. was found in 3 of the 7 orchards on twigs, leaves and fruit but in low numbers. *Parapronematus acaciae* was found in all but one orchard in all habitats except flowers.

Tydeid mites identified from other orchards throughout Florida (1997-1999).

The tydeid fauna associated with citrus throughout Florida between 1997 and 1999 are listed in Table 3-4. Five species of Tydeidae: *L. formosa*, *P. mumai*, *T. californicus*, *T. gloveri*, and *P. acaciae* were found in 19 orchards in 9 counties.

Table 3-3. Tydeidae mites associated with citrus in selected orchards in Florida, 1995-1996.

ORCHARD	CULTIVAR	PLANT HABITAT	*L. formosa*	*P. mumai*	*P. shawi*	*T. californicus*	*T. gloveri*	*T. munsteri*	*Apopronematus sp.*	*Metapronematus sp.*	*P. acaciae*
Polk Co.											
Trask	'Hamlin' orange	twigs	Apr, Aug, Nov 95, Jan 96	Apr, Nov 95			Jan 96				
		leaves	Jan to May, Jul, Sep to Nov 95, Jan 96	Oct 95		Feb, Apr, Oct, Nov 95, Jan 96	Mar, May 95				
		fruit	Jan to May, Jul, Sep to Nov 95	Oct 95			May 95				
		trunk brushings	Jan to Mar 95		Jan to Mar 95				Feb, Mar 95		
		flowers	Mar 95								
Yarborough	'Hamlin' orange	twigs	Apr, May, Nov 95, Jan 96								
		leaves	Jan to May, Jul to Sep, Nov 95, Jan 96	Sep 95, Jan 96				Mar 95, Jan 96		Jul 95	Feb, Sep 95
		fruit	Jan to May, Aug, Nov 95, Jan 96	Mar 95							Aug, Nov 95
		trunk brushings	Jan to Mar 95		Jan to Mar 95			Mar 95			
		flowers	Mar 95								

Table 3-3 continued

ORCHARD	CULTIVAR	PLANT HABITAT	*L. formosa*	*P. mumai*	*P. shawi*	*T. californicus*	*T. gloveri*	*T. munsteri*	*Apopronematus sp.*	*Metapronematus sp.*	*P. acaciae*
Pollard	'Duncan' and 'Marsh' grapefruit	twigs	Feb, Apr, May, Sep, Nov 95, Jan 96	Nov 95							
		leaves	Jan to May, Aug to Nov 95, Jan 96	Nov 95			Jul, Aug 95				
		fruit	Jan to May, Sep, Nov 95, Jan 96	Feb 95, Jan 96			Mar 95				
		trunk brushings	Jan to Mar 95		Mar 95				Jan 95		Jan 95
		flowers	Mar 95								
Lake Co.											
Hart I	'Ambersweet' orange	Twigs	Apr, May, Oct, Nov 95	Nov 95		Jan 96	Apr, May 95			May 95	
		leaves	Jan to May, Jul to Nov 95, Jan 96				Jan 96				
		fruit	Jan to May, Jul, Sep to Nov 95, Jan 96	May, Nov 95			Apr, May, Oct 95				Nov 95
		trunk brushings	Jan to Mar 95								Jan 95
		flowers	Mar 95								

Table 3-3 continued

ORCHARD	CULTIVAR	PLANT HABITAT	*L. formosa*	*P. mumai*	*P. shawi*	*T. californicus*	*T. gloveri*	*T. munsteri*	*Apopronematus sp.*	*Metapronematus sp.*	*P. acaciae*
Hart II	navel orange	twigs	Apr, May, Aug to Nov 95, Jan 96	Oct 95			Aug 95				
		leaves	Jan to May, Jul to Nov 95, Jan 96	Sep 95, Jan 96							Apr 95
		fruit	Jan to May, Jul, Sep to Nov 95, Jul 96	Jan, Apr, Nov 95				Mar 95			Jan 95
		trunk brushings	Jan to Mar 95	Feb 95							Jan 95
		flowers	Mar 95								
DeSoto Co.											
Mixon I	'Marsh' grapefruit	Twigs	Apr, May 95	Apr, May, Nov 95, Jan 96			Apr 95			Jan 96	Nov 95
		leaves	Jan to May, Oct, Nov 95, Jan 96	Jan to Apr, Oct, Nov 95, Jan 96			Jan to Mar 95	Feb to May 95			Jan, Feb, May, Oct, Nov 95, Jan 96
		fruit	Feb to May 95, Jan 96	Jan to May, Oct, Nov 95, Jan 96			Apr, Nov 95	Feb, May 95			Jan, May, Sep to Nov 95
		trunk brushings	Mar 95		Mar 95						

Table 3-3 continued

ORCHARD	CULTIVAR	PLANT HABITAT	*L. formosa*	*P. mumai*	*P. shawi*	*T. californicus*	*T. gloveri*	*T. munsteri*	*Apopronematus sp.*	*Metapronematus sp.*	*P. acaciae*
Mixon II	'Valencia' orange	twigs	Apr, May, Nov 95, Jan 96	May, Nov 95, Jan 96			Apr, Nov 95				Apr 95, Jan 96
		leaves	Jan to May, Sep to Nov 95, Jan 96	Jan to Mar, May, Oct, Nov 95, Jan 96			Jan, Mar to May, Jul, Sep to Nov 95, Jan 96	Jan to Mar, May, Oct 95			Jan to Mar, May, Oct, Nov 95, Jan 96
		fruit	Jan to May, Nov 95, Jan 96	Jan, Feb, Apr, May, Oct 95, Jan 96			Jan to May, Oct, Nov 95	Mar 95			Jan to Mar, May, Oct, Nov 95, Jan 96
		trunk brushings	Jan, Mar 95	Mar 95							

Notes on the species collected

A qualitative survey was completed to determine the tydeid fauna in various citrus habitats throughout the year. *Lorryia formosa* was found in 12 of the sampled orchards, most commonly found on leaves, but also from fruit and twigs.

Pseudolorryia mumai was found in low numbers ranging from 1 to 2 per 50 leaves in several of the orchards and on twigs, ranging from 1 to 6 per 10 twigs and on fruit, with 1 to 7 per 25 fruit. At the Becker site, *P. mumai* was collected in higher numbers than *L. formosa*.

Tydeus californicus was found in low numbers ranging from 1 to 2 per 50 leaves in a few of the orchards sampled. *Tydeus gloveri* was the prevalent species collected in higher numbers from several of the same sites on leaves, twigs and fruit. Numbers of *T. gloveri* were higher at Becker with 39 per 10 twigs, 2 per 25 fruit and 3 per 50 leaves while those for *L. formosa* and *P. mumai* were 1 per 50 leaves for both species, and 1 per 20 fruit for *P. mumai*. *Parapronematus acaciae* was found in several of the orchards in low numbers on fruit, leaves and, to a lesser extent, on twigs.

Tydeid mites identified from citrus orchards located in Texas and Louisiana (1999).

The tydeid fauna on citrus collected in January and February 1999 from Texas and Louisiana is shown in Table 3-5. *Lorryia formosa*, *P. mumai*, and *T. californicus* were collected from Texas and *L. formosa*, *P. mumai*, *T. californicus,* and *T. munsteri* from Louisiana.

Table 3-4. Tydeidae mites associated with citrus in selected orchards in Florida, 1997-1999.

ORCHARD	CULTIVAR	PLANT HABITAT	*L. formosa*	*P. mumai*	*T. californicus*	*T. gloveri*	*P. acaciae*
Dade Co.							
TREC	grapefruit	inner leaves		5 Mar 99			5 Mar 99
(Homestead)	lemon	dead twigs		5 Mar 99			
	mature lime	inner leaves		5 Mar 99			
	mature lime	10 twigs		5 Mar 99			
	lime	dead twigs		5 Mar 99			
	lemon	inner leaves		5 Mar 99		5 Mar 99	5 Mar 99
	orange	leaves		10 Nov 99			5 Mar 99
	grapefruit	20 fruit				5 Mar 99	5 Mar 99
	orange	50 leaves				5 Mar 99	
	'Green Shaddock'	leaves					10 Nov 99
Quail Roost	'Tahiti' lime	inner leaves				5 Mar 99	
(Homestead)	'Tahiti' lime	10 twigs				5 Mar 99	
	'Tahiti' lime	20 mature fruit				5 Mar 99	
	'Tahiti' lime	immature fruit				5 Mar 99	
DeSoto Co.							
Joshua,	'Pineapple'	leaves	17 Apr 97	17 Apr 97		17 Apr 97	17 Apr 97
Orange-co	orange						
(Arcadia)							
LM Stewart	'Valencia'	10 twigs	2 Mar 99	2 Mar 99		2 Mar 99	
(Arcadia)	orange						
	'Valencia'	20 fruit				2 Mar 99	
	orange						
Ft. Ogden	oranges	10 twigs	2 Mar 99				
	oranges	20 fruit	2 Mar 99			2 Mar 99	

Table 3-4 continued

ORCHARD	CULTIVAR	PLANT HABITAT	*L. formosa*	*P. mumai*	*T. californicus*	*T. gloveri*	*P. acaciae*
	'Pineapple' orange	50 outer leaves				2 Mar 99	
	'Pineapple' orange	50 inner leaves				2 Mar 99	
	'Pineapple' orange	10 twigs				2 Mar 99	
Hardee Co.							
Ona (Wauchula)	grapefruit	leaves	22 Jul 98		22 Jul 98		
	orange	leaves	22 Jul 98				22 Jul 98
	orange	Fruit					22 Jul 98
	orange	leaves + twigs					22 Jul 98
	grapefruit	leaves + twigs	22 Jul 98	22 Jul 98			
	grapefruit	fruit	22 Jul 98	22 Jul 98			22 Jul 98
Lafon (Bowling Green)	'Duncan' grapefruit	10 twigs	2 Mar 99				
	'Duncan' grapefruit	50 outer leaves	2 Mar 99				
	Duncan' grapefruit	50 inner leaves	2 Mar 99				
		10 twigs	2 Mar 99				
Hendry Co.							
Duda (Felda)	navel orange	leaves		1 Oct 98			
	red grapefruit	fruit					1 Oct 98

Table 3-4 continued

ORCHARD	CULTIVAR	PLANT HABITAT	*L. formosa*	*P. mumai*	*T. californicus*	*T. gloveri*	*P. acaciae*
	red grapefruit	fruit					19 Oct 98
	red grapefruit	fruit				27 Oct 98	
CPI (Ft. Myers)	red grapefruit	fruit				1 Oct 98	
	red grapefruit	Fruit				19 Oct 98	
Faryna (Montverde)	'Hamlin' orange	leaves	19 Mar 95				
	'Hamlin' orange	leaves	4 Jun 98				
	'Hamlin' orange	leaves					16 Sep 98
Lee Co.							
Frank Green (Alva)	'Valencia' orange	50 outer leaves			2 Mar 99		
		50 inner leaves			2 Mar 99		
Jay R (Alva)	volunteer citrus	leaves	2 Mar 99		2 Mar 99		
	volunteer citrus	10 twigs		2 Mar 99			

Table 3-4 continued

ORCHARD	CULTIVAR	PLANT HABITAT	*L. formosa*	*P. mumai*	*T. californicus*	*T. gloveri*	*P. acaciae*
Manatee Co.							
Unidentified	'Marsh' and red grapefruit	leaves	27 Aug 97	27 Aug 97			
	'Marsh' and red grapefruit	fruit	27 Aug 97	27 Aug 97		27 Aug 97	27 Aug 97
Martin Co.							
Becker	'Marsh' grapefruit	50 inner leaves		4 Mar 99		4 Mar 99	4 Mar 99
		50 outer leaves	4 Mar 99				4 Mar 99
		20 fruit		4 Mar 99		4 Mar 99	4 Mar 99
		10 twigs		4 Mar 99		4 Mar 99	4 Mar 99
St. Lucie Co.							
Driscoll (Ft. Pierce)	'Marsh' grapefruit	20 fruit					4 Mar 99
		50 inner leaves	4 Mar 99				4 Mar 99
	'Marsh' grapefruit	50 outer leaves	4 Mar 99				4 Mar 99
Dunn Grove (Ft. Pierce)	'Marsh' grapefruit	10 twigs				4 Mar 99	

Table 3-4 continued

ORCHARD	CULTIVAR	PLANT HABITAT	*L. formosa*	*P. mumai*	*T. californicus*	*T. gloveri*	*P. acaciae*
		20 fruit				4 Mar 99	4 Mar 99
		50 outer leaves				4 Mar 99	
Girl Scout (Ft. Pierce)	grapefruit	20 fruit	4 Mar 99				
	'Valencia' orange	20 fruit		4 Mar 99			4 Mar 99
		50 inner leaves			4 Mar 99		
	'Valencia' orange	50 outer leaves		4 Mar 99			
Next to Girl Scout (Ft. Pierce)	grapefruit	50 inner leaves	4 Mar 99				4 Mar 99
Next to Girl Scout	grapefruit	50 outer leaves	4 Mar 99				
	grapefruit	10 inner twigs	4 Mar 99				
	grapefruit	20 fruit	4 Mar 99				4 Mar 99
Ray Heffner (Ft. Pierce)	grapefruit	50 inner leaves		4 Mar 99			
	unidentified variety	20 fruit				4 Mar 99	
		50 outer leaves	4 Mar 99			4 Mar 99	

Notes about the species collected.

In Texas, 3 species were found together at the West Farm on red grapefruit. *Pseudolorryia mumai* was found on twigs and leaves and occurred more frequently in Texas. *Lorryia formosa* and *T. californicus* were collected once each from grapefruit.

In Louisiana, 4 species were found together on navel orange fruit in one location, i.e., *L. formosa*, *P. mumai*, *T. californicus*, and *T. munsteri*, while 3 species were collected from inner leaves and twigs on navel orange, i.e., *L. formosa*, *P. mumai*, and *T. californicus*. *Pseudolorryia mumai* was found more frequently on fruit, leaves and twigs in most of the habitats sampled in Louisiana. *Lorryia formosa* was the second species recovered more times from Louisiana orchards on fruit, leaves, and twigs along with *T. californicus* and *T. munsteri* on fruit and leaves.

Tydeidae collected from other citrus producing countries (1997-1999).

The tydeid fauna from citrus in Bahamas, Brazil, Dominican Republic, Italy, Morocco, Portugal, and Spain are listed in Table 3-6. Samples were based on single collection dates between January 1997 and May 1999. *Tydeus gloveri* was collected from white grapefruit in Great Abaco Island, Bahamas in January 1997. The tydeid species collected during these surveys were: *L. formosa*, *P. mumai*, *T. californicus*, *T. gloveri* and *P. acaciae*.

Notes on the species collected.

Lorryia formosa was found in Brazil, Morocco, Portugal and Spain on fruit and leaves. *Pseudolorryia mumai* was not found in the Mediterranean region, but it was

Table 3-5. Tydeidae mites associated with citrus in selected orchards in Texas and Louisiana, January-February, 1999.

ORCHARD	CULTIVAR	PLANT HABITAT	*L. formosa*	*P. mumai*	*T. californicus*	*T. munsteri*
TEXAS						
Hidalgo Co.						
South Farm (Weslaco)	grapefruit	20 inner twigs		29 Jan 99		
West Farm (Mission)	grapefruit	50 inner leaves		29 Jan 99		
		50 outer leaves		29 Jan 99		
West Farm	red grapefruit	10 twigs	29 Jan 99	29 Jan 99	29 Jan 99	
		20 fruit		29 Jan 99		
LOUISIANA						
Plaquemines Parish						
Eppley (Stella)	tangerine	fruit	1 Feb 99	1 Feb 99		
J. Sisk (West Pointe a la Hache)	mandarin	fruit	1 Feb 99	1 Feb 99		
		50 outer leaves		1 Feb 99		
		twigs		1 Feb 99		
	navel orange	twigs		1 Feb 99		
		fruit				1 Feb 99
		50 inner leaves		1 Feb 99		
		50 outer leaves		1 Feb 99	1 Feb 99	
Jesuit Bend	navel orange	20 fruit		1 Feb 99		
		leaves		1 Feb 99		

Table 3-5 continued

ORCHARD	CULTIVAR	PLANT HABITAT	*L. formosa*	*P. mumai*	*T. californicus*	*T. munsteri*
Lester (Stella)	tangerine	fruit		1 Feb 99		
Rinataza (Jesuit Bend)	mandarin	50 inner leaves				1 Feb 99
Rinataza	mandarin	50 outer leaves		1 Feb 99	1 Feb 99	
Rinataza	navel orange	50 inner leaves	1 Feb 99	1 Feb 99	1 Feb 99	
		50 outer leaves	1 Feb 99	1 Feb 99		1 Feb 99
		20 fruit	1 Feb 99	1 Feb 99	1 Feb 99	1 Feb 99
		twigs	1 Feb 99	1 Feb 99	1 Feb 99	
	mandarin	twigs	1 Feb 99			

Table 3-6. Tydeidae mites associated with citrus in selected orchards in different countries, 1997-1999.

ORCHARD	CULTIVAR	PLANT HABITAT	*L. formosa*	*P. mumai*	*T. californicus*	*T. gloveri*	*P. acaciae*
Bahamas							
Great Abaco Island	red grapefruit	leaves				3 Jan 97	
Brazil							
Cordeiropolis, Sao Paulo	mandarin	fruit	3 Jun 98				
	mandarin	leaves + twigs					3 Jun 98
Limeira, Sao Paulo	mandarin	fruit		4 Jun 98			
Piracicaba, Sao Paulo	citrus collection	leaves + wood		5 Jun 98			
Piracicaba, Sao Paulo	citrus collection	leaves		5 Jun 98			
Registro, Sao Paulo	mandarin	fruit	2 Jun 98				2 Jun 98
	mandarin	leaves					2 Jun 98
		leaves + twigs					2 Jun 98
Dominican Republic							
Hato Mayor, CCE Jimenez	'Valencia' orange	leaves		22 Mar 99			
Hato Mayor, JR Frank Manchado	'Valencia' orange	dead twigs		23 Mar 99			

Table 3-6 continued

ORCHARD	CULTIVAR	PLANT HABITAT	*L. formosa*	*P. mumai*	*T. californicus*	*T. gloveri*	*P. acaciae*
Hato Mayor, JR Frank Cholito	'Valencia orange	fruit		23 Mar 99			
Hato Mayor, Barcelo	'Valencia' orange	leaves					22 Mar 99
Hato Mayor, Barcelo	'Valencia' orange	inner leaves					23 Mar 99
Italy							
Medician Village, Florence	citrus collection	leaves			17 May 99		
Morocco							
Mimosa, Sale	grapefruit	leaves	8 May 99		8 May 99		
		fruitlets	8 May 99		8 May 99		
		fruit	8 May 99				
Kenitra	'Clementina' mandarin	leaves	8 May 99				
Larache	'Clementina' mandarin	leaves	8 May 99				
Rabat	sour orange	leaves			9 May 99		
Temisia, Agadir	citrus	leaves			10 May 99		
	sour orange	fruit			10 May 99		
Tikiovine, Agadir	citrus	fruit	10 May 99		10 May 99		
	citrus	leaves			10 May 99		

Table 3-6 continued

ORCHARD	CULTIVAR	PLANT HABITAT	*L. formosa*	*P. mumai*	*T. californicus*	*T. gloveri*	*P. acaciae*
Portugal							
Algos, Silves	'Valencia' late	leaves	25 May 99		25 May 99		
Antena, Silves	'Valencia' late	leaves			25 May 99		
Spain							
Riola, Valencia	orange	leaves	13 May 99		13 May 99		
Sueca, Valencia	orange	leaves			13 May 99		

collected from fruit, leaves and wood of citrus in Brazil and Dominican Republic. In Brazil, *P. mumai* was also collected from *Mimosa caesalpiniaefolia* Bentham, a tree species used as a windbreak in citrus orchards in São Paulo State.

Tydeus californicus was a common species found in the Mediterranean region and collected from leaves and fruit in Morocco, Spain, Portugal, and from potted citrus trees in the Medician Village in Florence, Italy. It was not collected from South America, Dominican Republic, or the Bahamas.

Tydeus gloveri was only recovered from grapefruit in the Bahamas. It is the only record in the CREC Tydeidae collection of this species found outside Florida. *Parapronematus acaciae* was recovered from orchards in Brazil and Dominican Republic but it was not found in samples collected in Europe or Morocco.

Key to species of Tydeidae found on citrus in Florida, Texas, Louisiana, and selected countries

1. Apotele I absent.....2
   Apotele I present.....4

2. Genu legs I and II each with three setae; genu leg III with two setae.....*Metapronematus* sp.
   Genu legs I and II each with two setae.....3

3. Genu leg III with two setae; (p2) reduced or absent on the prodorsum; trochanter leg II nude, forked setae on femora III and IV; femur leg IV not divided .....*Parapronematus acaciae*
   Genu and trochanter leg III each with one seta; (p2) normal. *Apopronematus* sp.

4. Femur leg III with two setae.....5
   Femur leg III with only one seta.....6

5. Femur leg II with three setae, reticulate pattern; smooth and broadly lanceolate dorsal body setae; curved distally.....
   .....*Lorryia formosa*
   Femur leg II with two setae; body medium size (160-225 μm); dorsal setae subequal in length, distally shorter than bothridial ones.....*Pseudolorryia mumai*

6. Femur leg II with three setae; none of setae very short. "Swirls" between setae c_1 and c_2 present
   .....*Paralorryia shawi*
   Femur leg II with two setae.....7

7. Four pairs of genital setae in adults.....*Tydeus munsteri*
   Six pairs of genital setae in adults.....8

8. Dorsal idiosomal setae of medium length: setae f_1 do not reach the bases of h_1, bothridial setae slightly longer than remaining dorsal ones.....*Tydeus californicus*
   Dorsal idiosomal setae relatively broadly lanceolate and stout: setae f_1 as long as 1/3 distance f_1-h_1; tricobothridial short, thickened and serrated.....*Tydeus gloveri*

Discussion

Tydeidae diversity on citrus is considerable. Several species have been identified from different important citrus-producing regions in the world, especially countries located in the Mediterranean area, e.g., Morocco, Algeria and Egypt, in northern Africa; Israel in the Middle East; and Portugal, Spain and Italy in southern Europe. Some of the species identified from this area have been collected in certain of the United States citrus-producing states, i.e., *T. californicus* and *P. ubiquitus* in California (McGregor 1956), and *L. formosa* and *T. californicus* in Florida, Louisiana, and Texas (present studies). *Tydeus gloveri* was only collected from Florida, and the Bahamas. *Pseudolorryia mumai* was collected from Texas, Louisiana, Brazil, and Dominican Republic. *Tydeus munsteri*, which was found in South Africa for the first time (Meyer & Ryke 1959), was collected only in Florida and Louisiana during these surveys.

Muma (1975) collected *L. floridensis*, *L. marcandrei*, *P. acaciae*, and *Triophtydeus* sp. from leaves; *P. shawi* from bark; *P. mumai* from leaves and bark; *T. gloveri* from fruit, leaves, and twigs, and *L.* sp. near *bedfordiensis* and *T. tuttlei* from litter, associated with citrus in Florida. Only *P. acaciae*, *P. mumai* and *T. gloveri* were found in the first survey of 1986-1987 f rom the species identified by Muma. These three species were collected again in the second survey conducted in 1995 and 1996, along with *P. shawi*, which was collected from bark. Despite collecting three *Lorryia* species, Muma did not find *L. formosa*. This was the most numerous species in the 1995-1996 survey in all habitats sampled and it was also numerous in the third Florida survey of 1997-1999. *Lorryia formosa* was collected from citrus in Texas and Louisiana, although its densities were not determined.

Lorryia formosa was reported associated with citrus in the Mediterranean countries such as Morocco, Spain and Algeria (Smirnoff 1959; Del Rivero 1962-1963; Thoreau-Pierre 1977). Nine tydeid species were identified on citrus in Spain (García-Marí et al. 1985, 1986). *Lorryia formosa* was the most commonly found species, especially on leaves and branches where it occurred in aggregations as observed in Florida citrus orchards.

Vacante and Nucifora (1984-1985) and Vacante (1988) reported *L. formosa* as one of the 11 species identified on citrus in Italy. *Lorryia formosa* was also reported from citrus in Portugal on leaves and the tree trunks of *C. sinensis*, *C. limon*, and *C. deliciosa* (Carmona 1970). She did not mention species densities or provide any other data about the species. *Lorryia formosa* was reported as a gregarious species, usually associated with *S. oleae* or with sooty mold (Benfatto 1980). Colonies were usually found on the underside of leaves.

Tydeus californicus was the most common tydeid species collected in the survey conducted in the Mediterranean region in 1999. Based on studies by García-Marí et al. (1985), this species was found more frequently between May and August, which coincides with the sampling period of the 1999 survey. In Egypt, it occurs in high densities during July and September (Rizk et al. 1978-1979c). Gerson (1971) considered this species as one of the most abundant on citrus in Israel. However, no data on population assessments were given. Gerson mentioned that thousands of *T. californicus* occurred on leaves, branches, and bark of citrus trees, as well as on annual and perennial weeds under the tree canopies. *Tydeus californicus* was collected in Florida as well, although its densities were low. *Tydeus californicus* was found in Texas and Louisiana in

single collections during February in this survey. No previous reports were found about this tydeid, its occurrence or abundance in either Texas or Louisiana. Reports by Banks (1904), Quayle (1912), McGregor (1932), McGregor (1956) mention *T. californicus* as an abundant species on citrus in California. The status of *T. californicus* in California today is not known.

Paralorryia shawi was collected from citrus tree trunk brushings in Florida and described from lichens and mosses in Mexico by Baker (1943, 1944). This species was only found from citrus trunk brushings in these surveys. *Parapronematus acaciae*, *Apopronematus* sp., and *Metapronematus* sp. were the three Pronematinae collected in Florida citrus. *Parapronematus acaciae* was also collected in Dominican Republic and Brazil. *Apopronematus* sp. and *Metapronematus* sp. were found for the first time on citrus and nothing is known about their biologies or seasonal occurrence. They are two new Tydeidae records to science.

The list of Tydeidae species associated with citrus has increased with this study, as well as the knowledge of their geographical distribution and citrus habitat preferences. More quantitative survey collections should be completed to determine the occurrence and complete distribution of Tydeidae related with citrus in Florida as well as worldwide.

CHAPTER 4
DISTRIBUTION, SPECIES ASSOCIATIONS, AND RELATIVE ABUNDANCE OF TYDEIDAE ON FLORIDA CITRUS

Introduction

The Tydeidae are a cosmopolitan family of mites with numerous species. Representatives of this family are often abundant and can be found on various host plants throughout the world. For instance, *T. californicus* was found associated with several ornamental trees and shrubs in Budapest, Hungary (Ripka & Kazmierski 1998). Tydeids can be particularly abundant on plants that have leaf domatia (tufts of hairs and other minute structures in the vein axils) (Walter & O'Dowd 1995), and some species can be abundant on microhabitats related with trunk bark (André 1986).

Smirnoff (1957, 1959) reported *L. formosa* associated with citrus trees in Morocco in the fall of 1955. He observed an accumulation of high populations at the base of small branches and petioles of leaves. In early spring of 1956, *L. formosa* reportedly coincided with the appearance of 3rd instar larvae of *S. oleae* and young females that produced abundant honeydew secretions in Morocco (Smirnoff 1957, 1959). Colonies of *L. formosa* were located at the proximal parts of citrus leaves and along the midribs. By the end of May, *L. formosa* migrated towards neighboring citrus trees, even those free of *S. oleae*. By the end of July, *L. formosa* appeared on young fruit and the females began laying eggs. Many *L. formosa* in all stages of development were sheltered under the cover of sepals, fruit and under their peduncles.

Rizk et al. (1978-1979c) reported *T. californicus* as being highly abundant on citrus leaves and shoots in the Minia region of Egypt, especially between July and September. They also found *P. ubiquitus* on leaves in low numbers.

García-Marí et al. (1985) studied the distribution and seasonal occurrence of tydeid mites in about 300 citrus orchards located in three important citrus-growing regions of Spain including Valencia, Murcia, and Andalucía. They found nine species of tydeids collected from leaves mainly in orchards that were usually sprayed with pesticides. *Lorryia formosa* was the prevalent species with maximum densities occurring in autumn and, to a lesser extent, in spring. The higher *L. formosa* densities were found on leaves and branches and formed aggregations (García-Marí et al. 1986). *Tydeus californicus* was the second species in importance. Other tydeid species found included *P. ubiquitus*, *T. caudatus*, *T. kochi*, and *L. reticulata*.

Local diversity of tydeids is often high, with many species sharing the same types of hosts and habitats. For example, Muma (1975) collected *T. gloveri* from fruit, leaves and twigs, *P. mumai* from leaves and bark, *L. floridensis*, *L. marcandrei*, *P. acaciae*, and *Triophtydeus* from leaves, *P. shawi*, from bark, and *L.* near *bedfordiensis*, and *T. tuttlei*, from litter, all from citrus in Florida.

This study reports on the distribution, species associations and relative abundance of tydeid species associated with citrus in seven selected orchards located in central and south central Florida between 1995 and 1996.

Materials and Methods

Tydeids were collected separately from 100 inner and outer leaves, 10 inner and outer twigs, 25 immature fruit, single mature fruit and 100 open flowers of citrus between January 1995 and January 1996. Brushings from tree trunks were collected only between January and March during 1995. Each sample was placed directly into a jar of 80% ethanol and returned to the laboratory. Samples were examined under a stereoscopic microscope and all mites present were separated by family, recorded, and placed in individual vials.

A black Petri dish bottom (135 mm inner diam by 25 mm depth with 35. 7 (~36) 20 x 20 mm grids, Falcon®1013, Becton Dickinson and Co.; Lincoln Park, NJ) was used to count the mites in each sample. When the tydeid mite populations were low (i.e., fewer than 100 individuals per sample), all mites in the dish were counted, recorded, and placed in a vial. When mite populations were high (i.e., 100 or more individuals), two, three, or six squares were selected randomly for counting, depending on mite density. Counts were then multiplied by 18, 12 or 6 respectively, to estimate the total population present. This procedure was used mostly for *L. formosa*.

Some of the 1995-1996 sites were re-visited between 1996 and 1999 and tydeids were collected. Mounting and identification procedures were the same as explained in Chapter 3. Ground cover plants and vines within the citrus orchards were sampled monthly in Trask, Pollard, Yarborough, Hart I, and Hart II. Flowers, when present, leaves and stems of individual ground cover plant species were placed directly into separate one-liter bottles containing 80% ethanol with appropriate collection data. A representative plant was collected in the field at the same time and placed in a plant press

for later identification to species. Plant identifications were completed by the Herbarium, Museum of Natural History, University of Florida, Gainesville.

Statistical Analysis

Analysis of *L. formosa* counts on inner and outer leaves in 5 orchards using ANOVA procedures were completed and analyzed using a SQRT ($x + 0.5$) transformation. Means were separated using PROC GLM (SAS Institute 1996). Untransformed means (±SE) are given in the text and figures, whereas statistical results refer to transformed data.

Results

Densities and relative abundance of Tydeidae mite species collected in seven citrus orchards in Florida, 1995-1996.

Lorryia formosa was found in the seven orchards sampled and occurred in the highest densities compared with the other tydeid species collected (Table 4-1). Species frequencies were similar in Yarborough, Hart I and Hart II. *Lorryia formosa* comprised 97% of the total tydeid populations in these three orchards, 98.5% in Pollard and 85.5% in Trask. Mixon I and II had frequencies of 65% and 67%, respectively.

Paralorryia shawi was collected in reduced numbers from 4 of the 7 sites with two specimens recovered from Mixon I and 503 from Trask. These frequencies never reached more than 0.5%. *Pseudolorryia mumai* was recovered from all seven sites in relatively low numbers except at Mixon I and II where it occurred at frequencies of 20% and 9% of the total estimated tydeid populations, respectively.

Table 4-1. Frequency comparisons of tydeid species and their relative abundance in seven citrus orchards located in central and south-central Florida (1995-1996).

Species	Trask (%)	Yarborough (%)	Pollard (%)	Hart I (%)	Hart II (%)	Mixon I (%)	Mixon II (%)
Lorryia formosa	392,849 (85.5%)	282,090 (97%)	433,022 (98.5%)	324,998 (97%)	165,547 (97%)	44,520 (65%)	43,363 (67%)
Paralorryia shawi	503 (<0.5%)	30 (<0.5%)	34 (<0.5%)	0	0	2 (<0.5%)	0
Pseudolorryia mumai	822 (<0.5%)	262 (<0.5%)	1,293 (0.5%)	317 (<0.5%)	5,035 (3%)	14,042 (20%)	6,082 (9%)
Tydeus californicus	6,288 (1.5%)	0	0	1,655 (0.5%)	0	0	0
Tydeus gloveri	58,944 (13%)	0	4,558 (1%)	8,963 (2.5%)	399 (<0.5%)	1,280 (2%)	6,340 (10%)
Tydeus munsteri	0	6,770 (2.5%)	0	0	21 (<0.5%)	3,296 (5%)	772 (1%)
Apopronematus sp.	1,070 (<0.5%)	25 (<0.5%)	9 (<0.5%)	0	0	0	0
Metapronematus sp.	0	2 (<0.5%)	0	0	2 (<0.5%)	1 (<0.5%)	0
Parapronematus acaciae	0	1,569 (0.5%)	15 (<0.5%)	12 (<0.5%)	74 (<0.5%)	5,500 (8%)	8,369 (13%)
TOTAL	460,476 (100%)	290,747 (100%)	438,931 (100%)	335,945 (100%)	171,078 (100%)	68,641 (100%)	64,926 (100%)

Tydeus californicus was only found in the Trask and Hart I sites in low densities. *Tydeus gloveri* was recovered from six of the seven sites, except for Yarborough. In total, 58,944 *T. gloveri* were recovered from Trask where this species was second in abundance and accounted for 13% of the total population. *Tydeus gloveri* comprised 10% of the total population in Mixon II, being third in abundance. *Tydeus munsteri* was found in 4 of the seven sites, comprising 2.5% in Yarborough and 5% in Mixon I compared with 1% in Mixon II and less than 0.5% in Hart II.

Apopronematus sp. was found in low densities only in the three sites in Polk County from tree trunk scrapings. *Apopronematus* sp. constituted less than 0.5% of the tydeid numbers in each of the same three locations, although 1,000 specimens were estimated from subsamples taken at the Trask site. *Metapronematus* sp. was found in low numbers in Yarborough, Hart II, and Mixon I, with no more than 2 specimens per site. *Parapronematus acaciae* was found in all sites but Trask. The highest frequencies consisted of 8% in Mixon I, which represented about 5,000 specimens and 13% in Mixon II with more than 8,000 tydeids from that site.

Seasonal occurrence and relative abundance of Tydeidae on leaves in seven citrus orchards in Florida, 1995-1996.

Fig. 4-1 shows the seasonal occurrence of Tydeidae in the Trask, Pollard, and Yarborough sites in Polk County. Populations of Tydeidae on inner leaves in the Trask, Pollard and Yarborough orchards began increasing in January or February and reached their highest peaks between April and May when densities were above 100 tydeids per leaf in each orchard. Tydeidae populations started to decrease in April in Pollard and

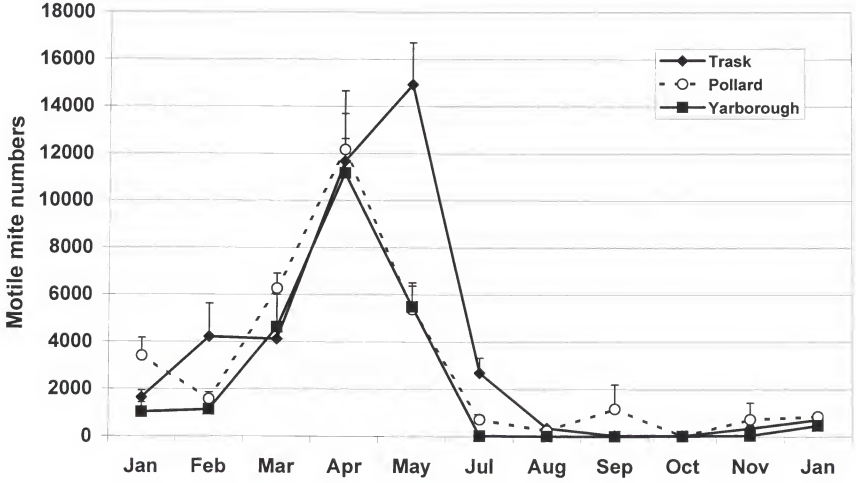


Fig. 4-1. Tydeidae populations on 100 inner leaves in Trask, Pollard and Yarborough orchards, Polk Co., Fla., 1995-1996.

Yarborough and in May in Trask and remained low to absent during the summer months in all three sites. The tydeid populations consisted mostly of *L. formosa*, although *T. californicus*, *T. gloveri* and *P. mumai* were also present on inner leaves.

Similar patterns were observed for outer leaves in the same orchards (Fig. 4-2). Peak densities of Tydeidae occurred during April. However, there was a different response between locations sampled. The highest numbers of Tydeidae were collected from the grapefruit orchard (Pollard) with 120 tydeids per leaf present during April. At the Trask site, 80 tydeids per leaf and less than 60 per leaf at Yarborough were recovered. Tydeid populations declined in all three locations after reaching their peaks in April. Their numbers were low to zero during July, August, September, and October, followed by a general increase beginning in November. As it occurred for inner leaves, *L. formosa* was the dominant species on outer leaves throughout the year in all three sites. Other tydeids collected from outer leaves were *T. gloveri*, *P. mumai*, *T. munsteri*, and *P. acaciae*.

The responses obtained from Hart I and II in Lake County were completely different from those in Polk County (Fig. 4-3). Two population peaks occurred on inner leaves at Hart I. The first peak occurred in February with 60 mites per leaf and the second in May with 50 mites per leaf. Both densities were considerably lower than the numbers obtained from the Trask, Pollard or Yarborough sites (Fig. 4-1). Tydeidae populations at the Hart I site declined after peaking in May and remained low through the summer months followed by an increase beginning in October. Hart II showed a different trend (Fig. 4-3). The main peak population for inner leaves was reached in May with 20 tydeids per leaf. The populations declined during the summer months and began

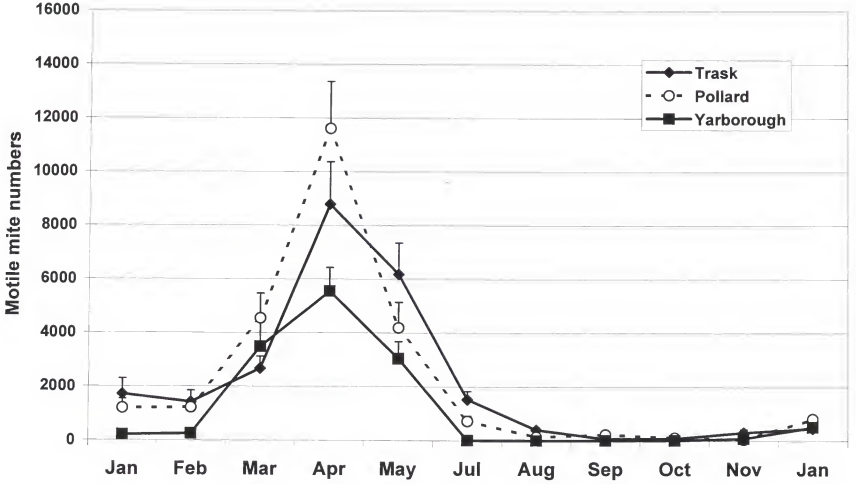


Fig. 4-2. Tydeidae populations on 100 outer leaves in Trask, Pollard and Yarborough orchards, Polk Co., Fla., 1995-1996.

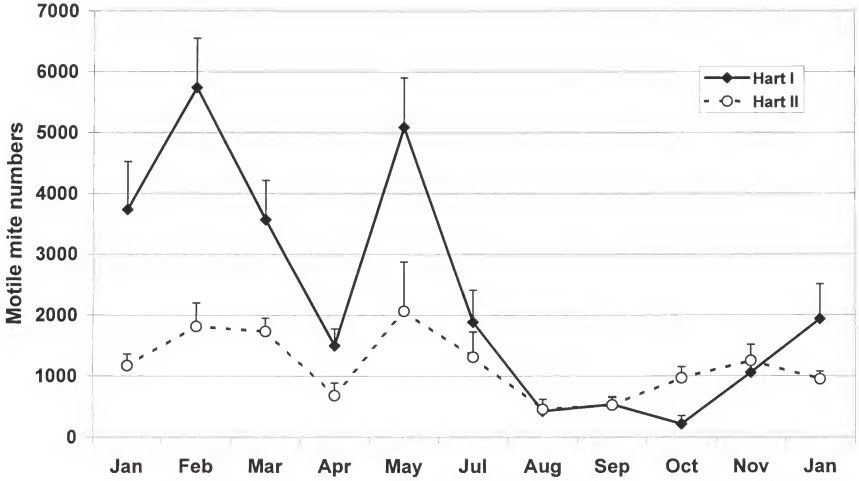


Fig. 4-3. Tydeidae populations on 100 inner leaves in Hart I and Hart II orchards, Lake Co., Fla., 1995-1996.

increasing again in September. *Lorryia formosa* was the prevalent mite species during the year in both locations. *Tydeus gloveri* was also collected from Hart I and *P. mumai* from Hart II.

The seasonal occurrence of *L. formosa* on outer leaves in the Hart sites showed a similar trend to that observed on inner leaves (Fig. 4-4). There was a first peak in February for Hart I with about 44 tydeids per leaf and a second peak in July with 35 mites per leaf and then declined abruptly. From February to March there was a major reduction in tydeid densities in Hart I. In Hart II, the population remained under 10 per leaf during the year with no peak densities occurring as in Hart I (Fig. 4-4). Populations in both sites consisted primarily of *L. formosa*. *Tydeus californicus* was collected in January, 1996 in Hart I and *P. acaciae* in Hart II in April, 1995.

The numbers of *L. formosa* recovered from inner leaves in Mixon I and II were low when compared with the densities found in the Polk County sites and were closer to the Lake County orchards (Fig. 4-5). In Mixon I, the populations began to increase in March, and peaked in May, with about 37 tydeids per leaf (Fig. 4-5). There was a total reduction in tydeid numbers after May and the population was mostly zero through the summer months. For Mixon II, the situation was similar but the peak population was reached in April with 28 mites per leaf (Fig. 4-5). The populations in Mixon I practically disappeared during the summer months. *Lorryia formosa* was present throughout the year in both orchards and occurred with *P. acaciae*, *P. mumai*, *T. gloveri*, and *T. munsteri*, especially during the spring and autumn.

The number of Tydeidae found on outer leaves in Mixon I and II was considerably lower compared with densities found on the inner leaves (Fig.4-6). The

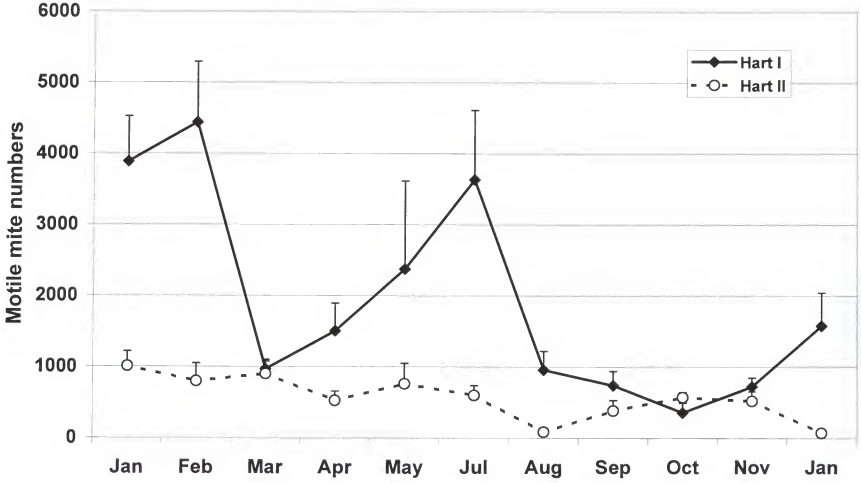


Fig. 4-4. Tydeidae populations on 100 outer leaves in Hart I and Hart II orchards, Lake Co., Fla., 1995-1996.

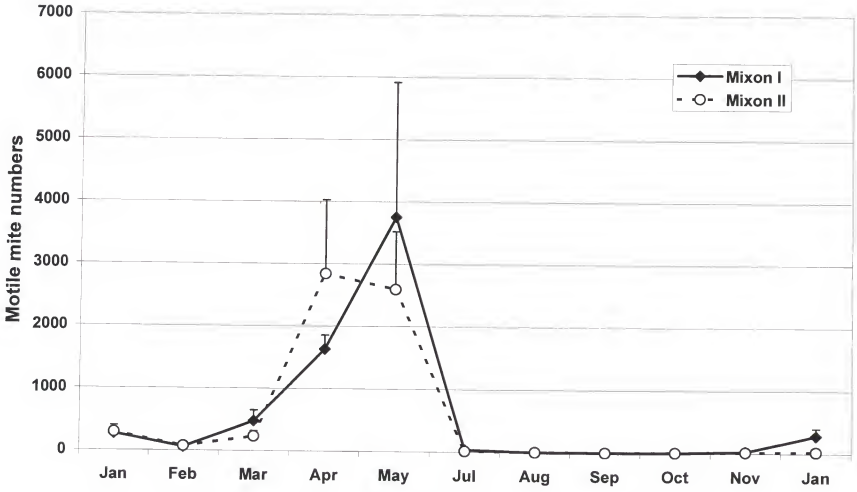


Fig. 4-5. Tydeidae populations on 100 inner leaves in Mixon I and Mixon II orchards, DeSoto Co., Fla., 1995-1996.

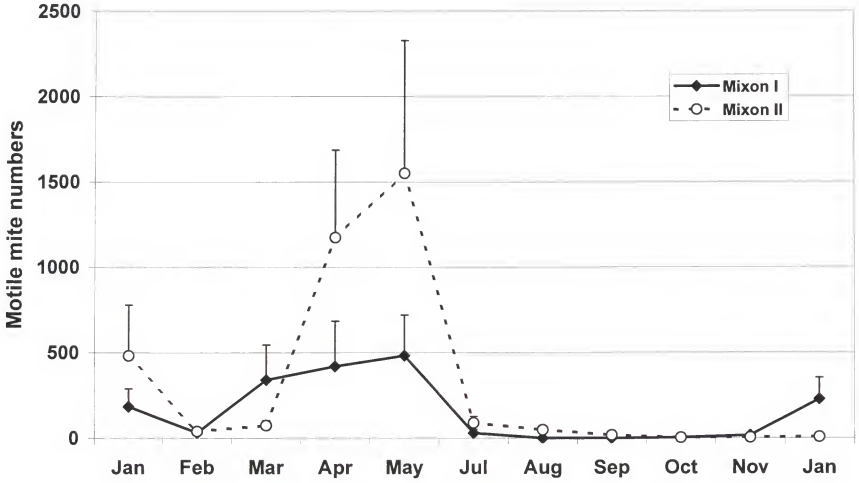


Fig. 4-6. Tydeidae populations on 100 outer leaves in Mixon I and Mixon II orchards, DeSoto Co., Fla., 1995-1996.

peak population in Mixon I was reached in May, when less than 5 mites per leaf were recovered. Densities were greatly reduced during the summer months. A larger number of Tydeidae was found in Mixon II, peaking in May with about 15 mites per leaf. The populations declined to near zero during the summer and then began to increase again in November at Mixon II. There was a mixture of tydeid species on both outer and inner leaves with *L. formosa* being the dominant species. *Pseudolorryia mumai*, *T. gloveri*, *T. munsteri*, and *P. acaciae* were also found on outer leaves at the Mixon II site.

Lorryia formosa was found in highest densities in most of the 7 sites sampled. However, during certain times of the year other tydeid species were also abundant. For instance, in Fig. 4-1, *L. formosa* was present in higher densities every month on inner leaves in the Trask orchard with the exception of May when *T. gloveri* was more numerous. After July all tydeid populations were significantly reduced and began to increase again in November.

Seasonal occurrence and relative abundance of Tydeidae on immature fruit in seven orchards in Florida, 1995.

Tydeid mites were collected on immature fruit from April to November, 1995. *Lorryia formosa* was the only tydeid recovered from immature fruit at the Trask orchard (Fig. 4-7). Sampling began in April when this species was recorded at densities of 957 per 25 fruit (38 per fruit). Densities increased in May with a peak of 126 per fruit. After that, their numbers gradually declined while fruit matured and expanded in size (Fig. 4-7).

Lorryia formosa was the dominant species on immature fruit in the Yarborough site (Fig. 4-7). The population had already peaked when sampling began in April with

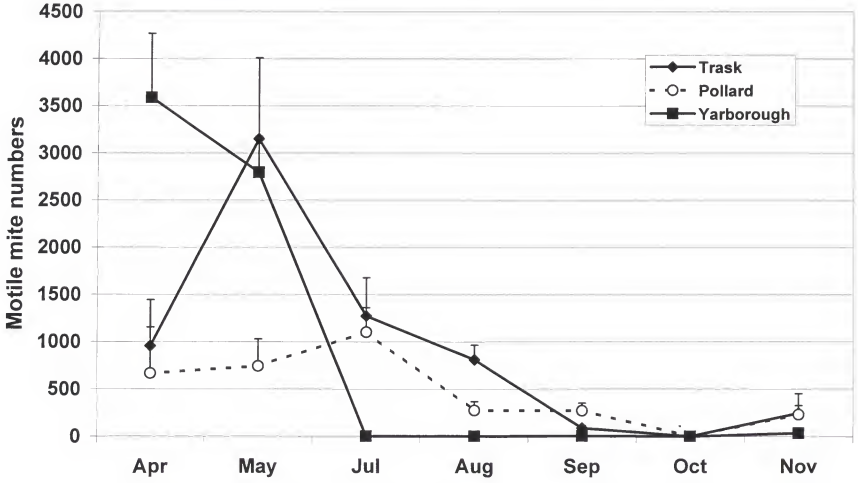


Fig. 4-7. Tydeidae populations on 25 immature fruit in Trask, Pollard and Yarborough orchards, Polk Co., Fla., 1995.

3,600 mites per 25 fruit (144 per fruit) and declined to zero in July. Only 11 specimens were recovered from samples collected in August with *L. formosa* consisting of 67% while 33% were *P. acaciae*. The Pollard orchard (white grapefruit) had the lowest densities of *L. formosa* on fruit compared to the two 'Hamlin' orange sites in Polk County (Fig. 4-7). A maximum density of 668 mites per 25 fruit was collected in April and then gradually increased to 40 per fruit in July followed by low densities occurring through the summer months. *Lorryia formosa* was the dominant species throughout the season and no other tydeid species were collected on immature fruit in the Pollard orchard.

In Hart I, the *L. formosa* population reached 800 individuals per 25 fruit (32 per fruit) in April, increased to 1700 mites per 25 fruit in July, and then declined dramatically to 15 mites per fruit in August (Fig. 4-8). The population began increasing slowly after August until reaching 400 per 25 fruit (16 per fruit) in September and then declined again (Fig. 4-8). In Hart II, the population peaked in April followed by general decline through October and then began increasing again (Fig. 4-8).

A mixture of tydeid species, i.e., *L. formosa*, *T. gloveri*, *T. munsteri*, *P. mumai*, and *P. acaciae* occurred on fruit at the Mixon I site. No single tydeid species was prevalent in this location throughout the year (Fig. 4-9). During the summer months the tydeid populations were either substantially reduced or absent in all orchard sites. *Lorryia formosa* was the only tydeid recovered in April and it was most abundant in May in the Mixon II site (Fig. 4-9). Reduced tydeid populations were detected between July and November.

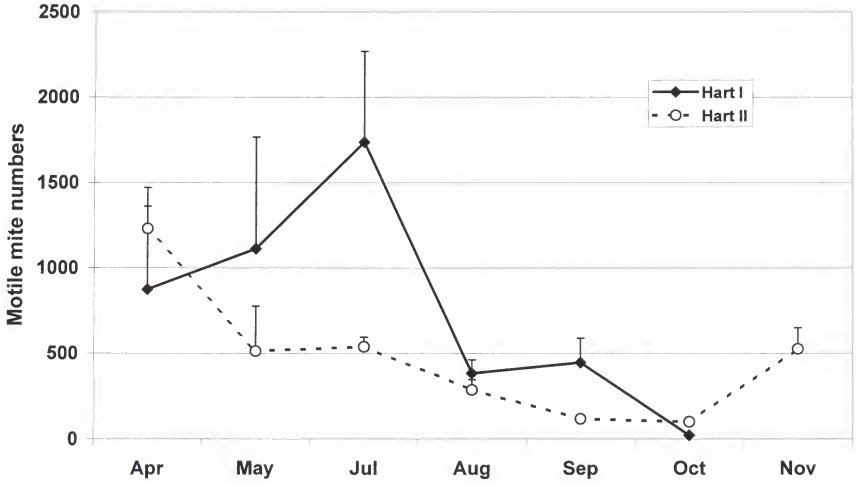


Fig. 4-8. Tydeidae populations on 25 immature fruit in Hart I and Hart II orchards, Lake Co., Fla., 1995.

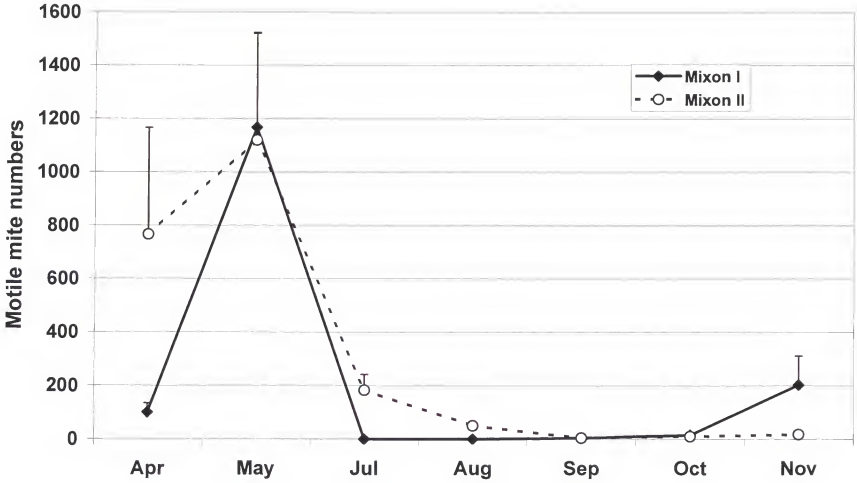


Fig. 4-9. Tydeidae populations on 25 immature fruit in Mixon I and Mixon II orchards, DeSoto Co., Fla., 1995.

Distribution and relative abundance of *Lorryia formosa* on inner and outer leaves in 5 citrus orchards.

Fig. 4-10 shows the distribution and relative abundance of *L. formosa* on leaves in the Trask orchard. Densities were similar in the months of January, from August to November, 1995 and January, 1996. Populations peaked in April in both groups of leaves. There was a trend toward lower *L. formosa* densities on outer leaves throughout the year; although, in most cases, it was not statistically significant. In the Trask orchard, there was statistical difference between densities for both habitats in February and May, being higher on inner leaves ($P<0.05$) ($df=10$; $F=3.43$; $P=0.0006$). The P values for leaf interaction in February and May were 0.0018 and 0.0001, respectively.

The Pollard orchard showed a similar trend observed in Trask (Fig. 4-11), and *L. formosa* peaked in April too. By May, there was a general decline in numbers for both habitats and they remained low for the remaining sample dates. In the Pollard orchard, only in January 1995, the difference between both habitats was statistically significant ($P<0.05$) ($df=10$; $F=0.92$; $P=0.5212$). The P value for leaf interaction in January 1995 was 0.0052.

A similar trend was observed for the Yarborough site (Fig. 4-12). Once again, the populations of *L. formosa* peaked in April reaching 110 mites per inner leaf and 55 per outer leaf. There was a reduction in numbers for May and an abrupt decline during the summer months. Inner leaf samples had significantly higher densities in April and May compared with other leaf samples in the Yarborough site (Fig. 4-12)($P<0.05$) ($df=10$; $F=2.16$; $P=0.0258$). The P values for leaf interaction in April and May were 0.0001 and 0.0073, respectively.

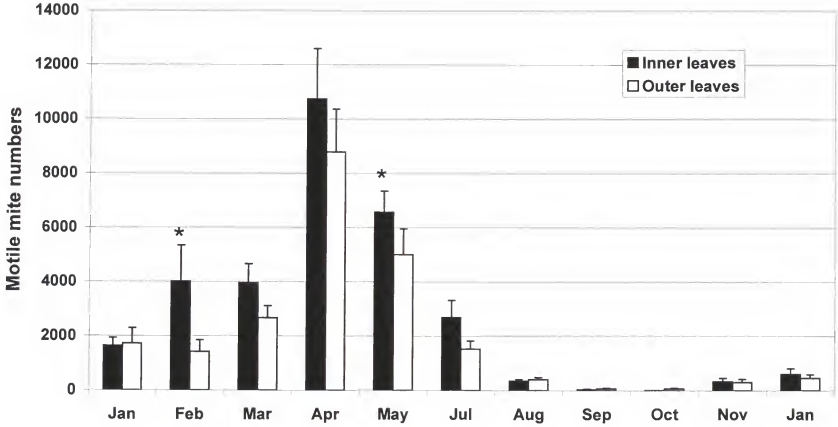


Fig. 4-10. *Lorryia formosa* on inner and outer leaves in the Trask orchard, Polk Co., Fla., 1995-1996. Asterisks indicate significant differences between sets of leaves.

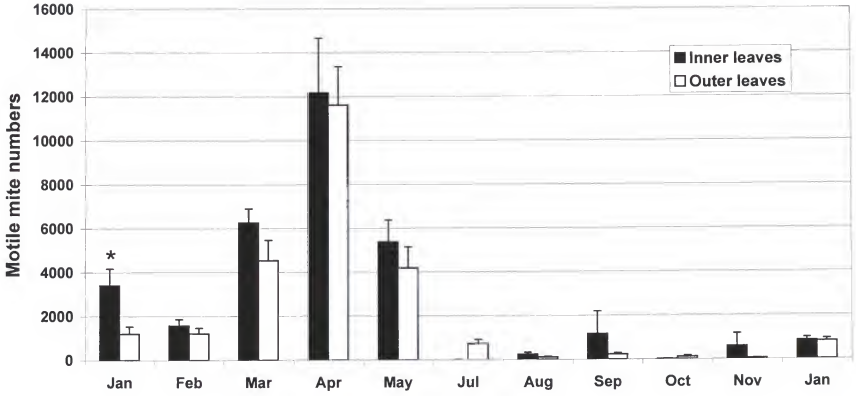


Fig. 4-11. *Lorryia formosa* on inner and outer leaves in the Pollard orchard, Polk Co., Fla., 1995-1996. Asterisk indicate significant differences between sets of leaves.

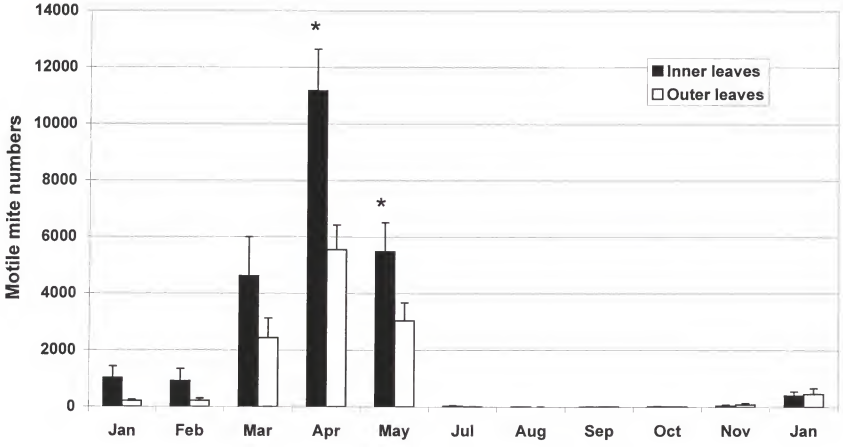


Fig. 4-12. *Lorryia formosa* on inner and outer leaves in the Yarborough orchard, Polk Co., Fla., 1995-1996. Asterisks indicate significant differences between sets of leaves.

Hart I had low densities of *L. formosa* on leaves, compared with the three sites in Polk Co. (Fig. 4-13). *Lorryia formosa* was most abundant in February with highest densities occurring on inner leaves, although there were no statistical differences between inner and outer leaf samples. Comparable numbers occurred in January, April and during the summer months except for July when *L. formosa* was collected in higher numbers from the outer leaves. Populations in March, May and July were statistically different in Hart I with higher numbers on inner leaves in March and May, and on outer leaves in July ($P<0.05$) ($df=10$; $F=3.52$; $P=0.0005$). The P values for leaf interaction in March, May and July were 0.0004, 0.0004 and 0.0161, respectively.

In Hart II, populations of *L. formosa* were higher on inner leaves than on outer leaves for all months (Fig. 4-14). Populations in Hart II were lower than in Hart I and both were substantially reduced when compared with the Polk County sites. Statistical differences between counts of *L. formosa* on inner and outer leaves occurred during February, March, May, July, October, and November 1995, and January 1996 at Hart II ($P<0.05$) ($df=10$; $F=2.21$; $P=0.0199$). The P values for leaf interaction in February, March, May, July, October, November 1995, and January 1996 were 0.0071, 0.0271, 0.0001, 0.0165, 0.0032, 0.0084, and 0.0001, respectively.

Distribution and relative abundance of Tydeidae on inner and outer leaves in 2 citrus orchards.

No single tydeid species was prevalent in the Mixon I site throughout the year. *Lorryia formosa* was most abundant in May with 35 mites per inner leaf (Fig. 4-15).

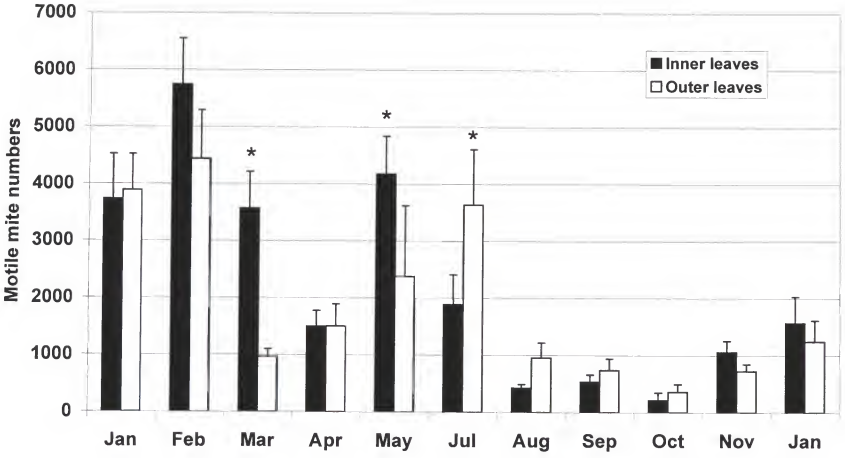


Fig. 4-13. *Lorryia formosa* on inner and outer leaves in the Hart I orchard, Lake Co., Fla., 1995-1996. Asterisks indicate significant differences between sets of leaves.

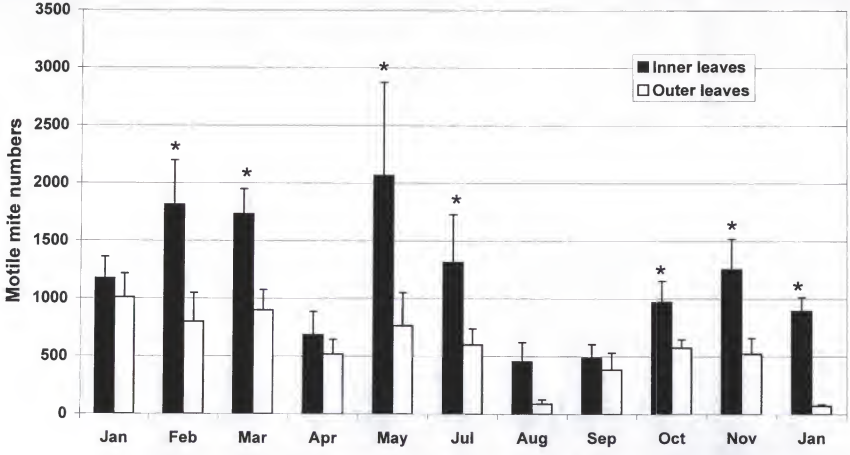


Fig. 4-14. *Lorryia formosa* on inner and outer leaves in the Hart II orchard, Lake Co., Fla., 1995-1996. Asterisks indicate significant differences between sets of leaves.

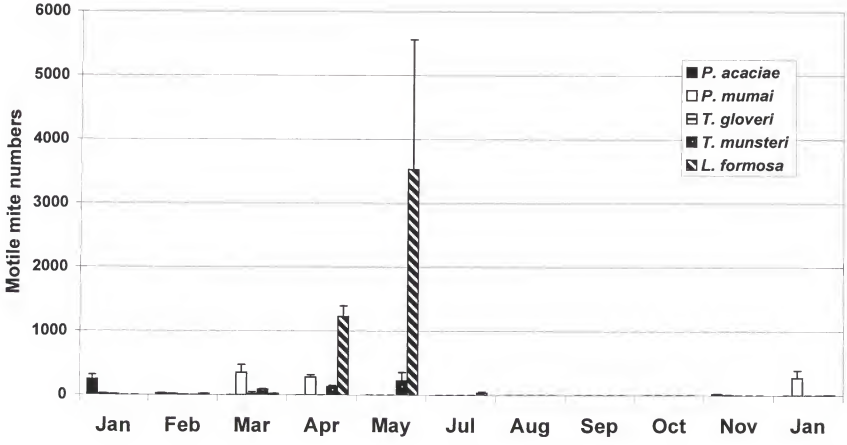


Fig. 4-15. Tydeidae species on 100 inner leaves in Mixon I orchard, DeSoto Co., Fla., 1995-1996.

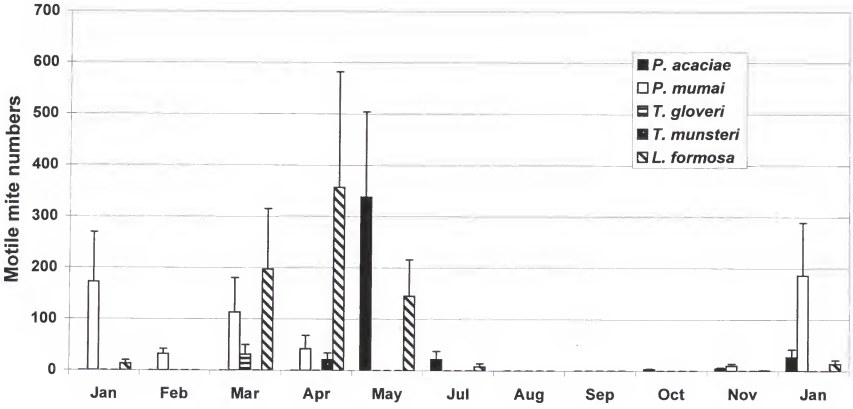


Fig. 4-16. Tydeidae species on 100 outer leaves in Mixon I orchard, DeSoto Co., Fla., 1995-1996.

A similar trend was observed for outer leaves, with *L. formosa* being the prevalent species found during March and April (Fig. 4-16). *Pseudolorryia mumai* was prevalent during January and February 1995 and January 1996. *Parapronematus acaciae* was prevalent during May on outer leaves and *L. formosa* was the second most abundant species.

In Mixon II, low populations were found throughout the year on inner leaves with *L. formosa* being the dominant species during April and May (Fig. 4-17). *Parapronematus acaciae* had the highest densities on inner leaves in January 1995.

Lorryia formosa was most abundant during April and May on outer leaves in Mixon II (Fig. 4-18). In January 1995, *L. formosa* and *P. acaciae* had similar densities of about 2 per leaf. *Tydeus gloveri* was the dominant species in July, but with lower densities compared to *L. formosa*. The remainder of the sample dates had substantially lower numbers of tydeid mites.

Tydeidae composition in citrus habitats other than leaves and immature fruit for seven orchards in Florida, 1995-1996.

Tydeids were collected in higher numbers and more frequently from leaves and immature fruit in the seven sites sampled compared with counts on twigs, mature fruit, tree trunk brushings and open flowers (Table 4-2).

Table 4-2 shows the distribution and relative abundance of tydeids in Trask, Yarborough and Pollard. *Lorryia formosa* was the only species found in the remaining five habitats listed. Along with leaves and immature fruit, *L. formosa* densities were highest on inner and outer twigs, principally in the Pollard orchard, where numbers of

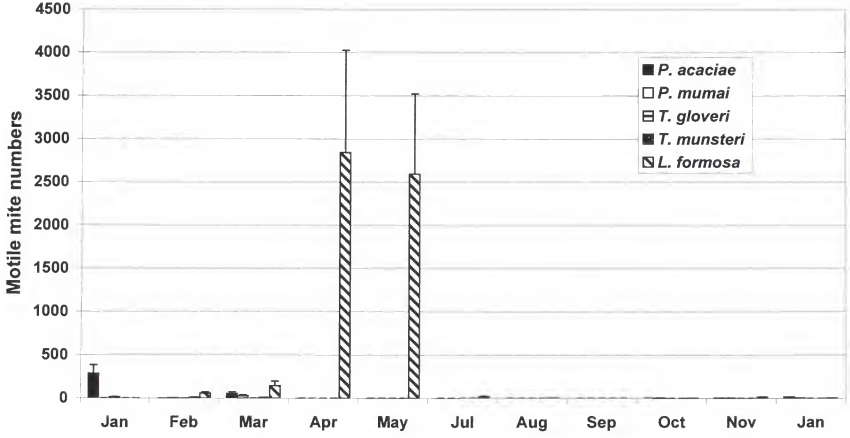


Fig. 4-17. Tydeidae species on 100 inner leaves in Mixon II orchard, DeSoto Co., Fla., 1995-1996.

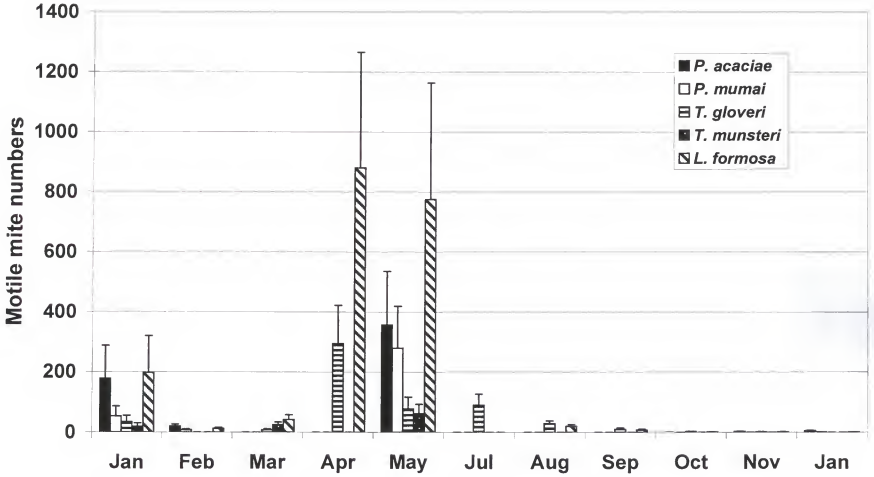


Fig. 4-18. Tydeidae species on 100 outer leaves in Mixon II orchard, DeSoto Co., Fla., 1995-1996.

Table 4-2. Numbers of Tydeidae found in citrus habitats other than leaves and immature fruit in three orchards, Polk Co., Fla., 1995-1996

	10 inner twigs	10 outer twigs	individual mature fruit	trunk brushings	100 open flowers	TOTAL
Trask:'Hamlin' orange						
L. formosa	9,598	6,770	436	1,086	313	18,203
T. californicus	0	0	0	0		0
T. gloveri	753	0	0	0	0	753
T. munsteri	0	0	0	0	0	0
P. mumai	747	0	0	0	0	747
P. shawi	0	0	0	503	0	503
P. acaciae	0	0	0	0	0	0
Apopronematus sp.	0	0	0	1,070	0	1,070
Yarborough: 'Hamlin'orange						
L. formosa	10,682	6,652	2,439	53	331	20,157
T. californicus	0	0	0	0	0	0
T. gloveri	0	0	0	0	0	0
T. munsteri	0	0	0	5	0	5
P. mumai	0	0	50	0	0	50
P. shawi	0	0	0	30	0	30
P. acaciae	0	0	0	0	0	0
Apopronematus sp.	0	0	0	25	0	25
Metapronematus sp.	0	0	0	0	0	0
Pollard: 'Duncan' and 'Marsh' grapefruit						
L. formosa	23,111	20,265	3,066	210	467	47,119
T. californicus	0	0	0	0	0	0

Table 4-2 continued

	10 inner twigs	10 outer twigs	individual mature fruit	trunk brushings	100 open flowers	TOTAL
T. gloveri	0	0	25	0	0	25
T. munsteri	0	0	0	0	0	0
P. mumai	14	0	59	0	0	73
P. shawi	0	0	0	34	0	34
P. acaciae	0	0	0	15	0	15
Apopronematus sp.	0	0	0	9	0	9

L. formosa exceeded 20,000 mites. Other species found on twigs were *T. gloveri* and *P. mumai* with 753 *T. gloveri*, the highest number recorded. *Lorryia formosa* was the only species collected from flowers in a range of 313 to 467 per 100 open flowers and *Apopronematus* sp. and *P. shawi* were collected only from tree trunk brushings in a range of 25 to 1,070 mites.

In Hart I and II, *L. formosa* was the dominant species, being mostly collected from inner twigs (Table 4-3). *Lorryia formosa* reached more than 16,000 mites on inner twigs in Hart I and 24,000 in Hart II during sampling. *Lorryia formosa* was the only species collected from open flowers in the Polk County orchards. *Tydeus gloveri* was also collected from inner twigs, but in low densities, with 1,340 mites in the Hart I site and 399 in Hart II. *Pseudolorryia mumai* was collected in reduced numbers from inner twigs with a maximum of 39 from Hart I and 936 in Hart II.

Lorryia formosa was prevalent in Mixon I on twigs and Mixon II on outer twigs and mature fruit but in lower numbers when compared with the other 5 sites (Table 4-4). Inner twigs supported higher *L. formosa* populations with a total of 5,300 mites collected in Mixon I and 2,023 on inner twigs in Mixon II. *Pseudolorryia mumai* was the second species in importance, considering the numbers found. This species was mostly recovered from twigs, especially in Mixon II with 2,990 collected from outer twigs compared with only 649 *L. formosa* during the year. *Tydeus gloveri* and *P. acaciae* were also collected from these orchards from all the habitats sampled except tree trunk brushings.

Table 4-3. Numbers of Tydeidae found in citrus habitats other than leaves and immature fruit in two orchards, Lake Co., Fla., 1995-1996

	10 inner twigs	10 outer twigs	individual mature fruit	trunk brushings	100 open flowers	TOTAL
Hart I: Ámbersweet' orange						
L. formosa	16,634	2,896	9,306	2,201	17	31,054
T. californicus	0	0	0	0	0	0
T. gloveri	1,340	224	0	0	0	1,564
T. munsteri	0	0	0	0	0	0
P. mumai	39	0	3	7	0	49
P. shawi	0	0	0	0	0	0
P. acaciae	0	0	4	8	0	12
Apopronematus sp.	0	0	0	0	0	0
Hart II: navel orange						
L. formosa	24,393	6,127	2,109	374	365	33,368
T. californicus	0	0	0	0	0	0
T. gloveri	399	0	0	0	0	399
T. munsteri	0	0	21	0	0	21
P. mumai	936	0	20	2	0	958
P. shawi	0	0	0	0	0	0
P. acaciae	0	0	8	3	0	74
Apopronematus sp.	0	0	0	0	0	0
Metapronematus sp.	1	0	0	0	0	1

Table 4-4. Numbers of Tydeidae found in citrus habitats other than leaves and immature fruit in two orchards, DeSoto Co., Fla., 1995-1996

	10 inner twigs	10 outer twigs	individual mature fruit	trunk brushings	TOTAL
Mixon I 'Marsh' grapefruit					
L. formosa	5,300	1,007	142	0	6,449
T. californicus	0	0	0	0	0
T. gloveri	61	14	12	0	87
T. munsteri	0	0	1	0	1
P. mumai	592	200	156	0	948
P. shawi	0	0	0	0	0
P. acaciae	20	0	58	0	78
Apopronematus sp.	0	0	0	0	0
Metapronematus sp.	1	0	0	0	1
Mixon II 'Valencia' orange					
L. formosa	2,023	649	1,153	13	3,838
T. californicus	0	0	0	0	0
T. gloveri	25	49	287	0	361
T. munsteri	0	0	0	0	0
P. mumai	192	2,990	159	3	3,344
P. shawi	0	0	0	0	0
P. acaciae	34	24	22	0	80
Apopronematus sp.	0	0	0	0	0

Tydeid mites found on ground cover plants associated with citrus trees in selected orchards.

Lorryia formosa, *P. mumai*, *T. gloveri*, *T. munsteri*, *P. acaciae*, and *Metapronematus* sp. were identified from 42 ground cover plant species distributed in 24 families (Table 4-5). More than 80 species of ground cover plants were sampled, but tydeids were found on only 42.

Lorryia formosa was recovered from 39 of the 42 positive ground cover plant species sampled. The three species without *L. formosa* were: *Emilia fosbergii* Nicolson, *Heterotheca subaxillaris* (Lamarck), both Compositae, which had *Metapronematus* sp. present and *Stachys floridana* Shuttleworth (Labiatae), which had only *P. mumai*. In some of the plants, the estimated densities for *L. formosa* were relatively higher, e.g., on *Solanum americanum* Miller, with 13,730 individuals found between January and August 1995 and on *Bidens alba* (L.), with 12,288 mites collected monthly from January to November 1995. In the remainder of the plants, *L. formosa* populations ranged from a few thousands, e.g. 5,953 on *Amaranthus spinosus* L. and 5,287 on *Gnaphalium pensylvanicum* Willdenow to less than 10 individuals in a small group of plants including *Gomphrena serrata* L., *Mikania scandens* (L.), *Panicum texanum* Buckley, and *Physalis angulata* L. (Table 4-5).

Fig. 4-19 shows a comparison between the densities of *L. formosa* found on leaves, immature fruit and three ground cover plants, *B. alba*, *A. spinosus* and *S. americanum*. These plants were found most frequently during the year in the Trask orchard. *Lorryia formosa* peaked on citrus leaves in April, being most abundant on the inner leaves. Populations of *L. formosa* on *B. alba* and *A. spinosus* also peaked in April

Table 4-5. Tydeid mites collected on ground cover plants or vines in five citrus orchards located in central and south central Florida, 1995-1996.

Plant Family	Ground cover or vine species	*L. formosa*	*P. mumai*	*T. gloveri*	*T. munsteri*	*P. acaciae*	*Metapronematus* sp.
Amarantaceae	*Amaranthus spinosus* L.	5953	661				
	A. viridis L.	154					
	Gomphrena serrata L.	8	46	15			
Brassicaceae	*Barbarea vulgaris* R. Brown	22					
Cariophyllaceae	*Stellaria media* (L.)	1004					
Chenopodiaceae	*Chenopodium album* L.	31					
Commelinaceae	*Commelina diffusa* F. Burman	17					
Compositae	*Ambrosia artemisiifolia* L.	1641					
	Gnaphalium pensylvanicum Willdenow	5287					
	Bidens alba (L)	12288	1365				
	Bidens sp.	38					
	Emilia fosbergii Nicolson						10
	Eupatorium capillifolium (Lamarck)	2661					
	Heterotheca subaxillaris (Lamarck)	720					6
	Mikania scandens (L.)	4	1				
	Sonchus asper (L.)	33					
	Taraxacum officinale Wiggens	1089					
	Youngia japonica (L.)	3418					
Convolvulaceae (*)	*Ipomoea hederifolia* L.	327					
Cruciferae	*Lepidium virginicum* L.	467					
Cyperaceae	*Cyperus retrorsus* Chapman	62					1
Euphorbiaceae	*Chamaesyce hirta* (L.)	29	2				1

Table 4-5 continued

Plant Family	Ground cover or vine species	*L. formosa*	*P. mumai*	*T. gloveri*	*T. munsteri*	*P. acaciae*	*Metapronematus* sp.
	C. hyssopifolia (L.)	28					1
Fumariaceae	*Fumaria officinalis* L.	31					
Gramineae	*Panicum texanum* Buckley	8					1
Labiatae	*Glechoma hederaceae* L.	32					
	Stachys floridana Shuttleworth		13				
Leguminosae	*Desmodium tortuosum* (Swartz)	209				31	
	Indigofera hirsuta Harvey	361	42	22			
Malvaceae	*Sida acuta* F. Burman	10					
Oxalidaceae	*Oxalis intermedia* A. Richard	123					
Phytolaccaceae	*Rivina humilis* L.	156			17		
Polygonaceae	*Rumex hastatulus* Baldwin	477					
Rubiaceae	*Richardia brasiliensis* Gomes	4702	261		261		3
Scrophulariaceae	*Scoparia dulcis* L.	333					
Solanaceae	*Physalis angulata L.*	9					
	Solanum americanum Miller	13730					
	S. douglasii Dunal	30					
	Solanum sp.	1712					
Umbelliferae	*Spermolepis divaricata* (Walter)	13					
Urticaceae	*Parietaria praetermissa* Hinton	2728					
Verbenaceae	*Lantana camara* L.	3390					

(*)vine

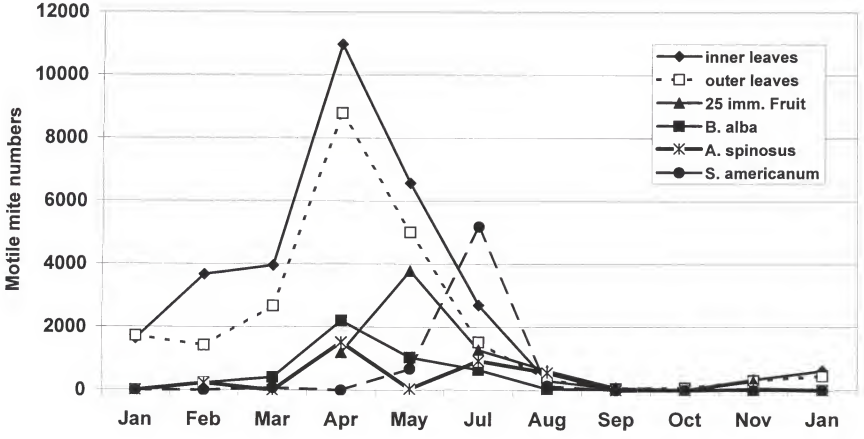


Fig. 4-19. Seasonal occurrence and relative abundance of *Lorryia formosa* on leaves, fruit and selected ground cover plants in the Trask orchard, Polk Co., Fla., 1995-1996.

but in considerably lower numbers, 2,000 mites estimated from *B. alba* and about 1,500 from *A. spinosus*. *Lorryia formosa* was recovered in greatest numbers in July on *S. americanum* when populations in the citrus trees had declined substantially. More than 5,000 individuals were recovered from *S. americanum* in July (Fig. 4-19). *Amaranthus spinosus* and *B. alba* were the two ground cover plants found most frequently throughout the year in the Pollard orchard (Fig. 4-20). *Lorryia formosa* densities were always lower on ground cover plants when compared to those found on leaves. However, the numbers were close to densities found on citrus fruit from May to August.

Only two ground cover plants, *B. alba* and *S. americanum*, were found more frequently throughout the year in the Yarborough orchard (Fig. 4-21). *Bidens alba* had a low population of *L. formosa* when compared with those on citrus leaves and fruit, and peaked in February and May. On *Solanum americanum*, which also had low populations of *L. formosa*, this species peaked in March. The populations on ground cover plants in Yarborough were low compared with those found on the citrus host.

The presence of *P. mumai* in the Trask and Yarborough orchards was not detected on leaves and fruit throughout the year, but it was collected from *B. alba* and *A. spinosus* in low numbers (Fig. 4-22). *Pseudolorryia mumai* peaked on *B. alba* in April in the Trask site and in February and May in the Yarborough orchard. *Pseudolorryia mumai* peaked on *A. spinosus* in April in Trask and there was a lower peak in July while being practically absent in the Yarborough site.

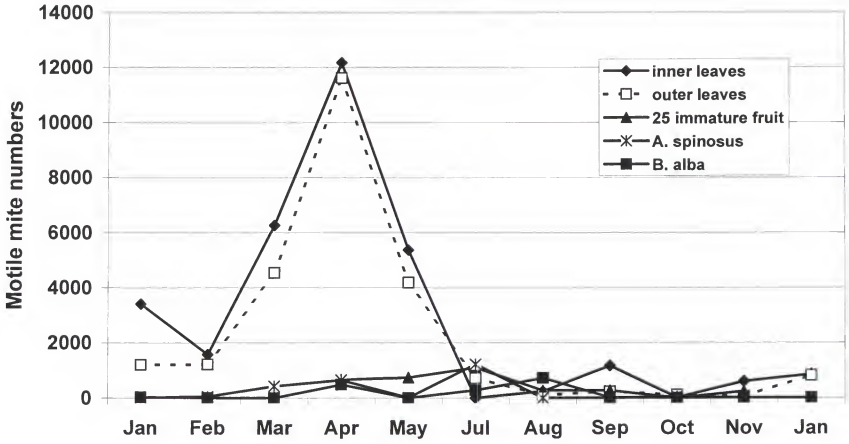


Fig. 4-20. Seasonal occurrence and relative abundance of *Lorryia formosa* on leaves, fruit and selected ground cover plants in the Pollard orchard, Polk Co., Fla., 1995-1996.

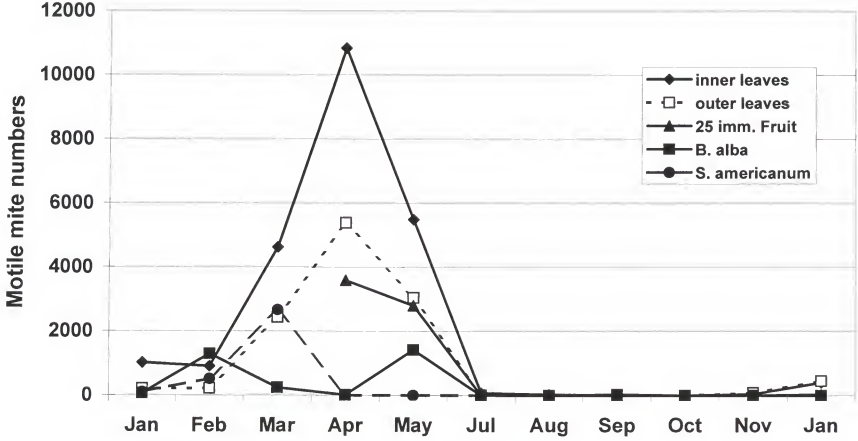


Fig. 4-21. Seasonal occurrence and relative abundance of *Lorryia formosa* on leaves, fruit and selected ground cover plants in the Yarborough orchard, Polk Co., Fla., 1995-1996.

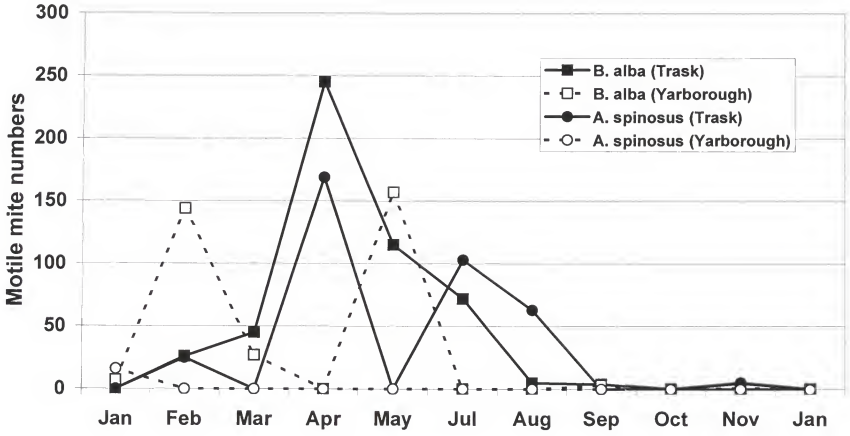


Fig. 4-22. Seasonal occurrence and relative abundance of *Pseudolorryia mumai* on selected ground cover plants in the Trask and Yarborough orchards, Polk Co., Fla., 1995-1996.

Discussion

Lorryia formosa was the most abundant tydeid species found in all citrus orchards sampled. It was observed in high densities and aggregated along the petioles and midribs of the lower leaf surface.

All stages of *L. formosa* were found on the inside bottom rims of white plastic cups used for monitoring aphid movement in March 1998 (Michaud, J.P. 1998. Personal communication). Since this substrate does not provide a food source it is believed that *L. formosa* was migrating from unknown hosts to the citrus trees. This hypothesis is reinforced by the fact that the highest populations found on citrus occurred between April and May. Numerous species of Acari migrate aerially by wind currents including many eriophyoid species (Nault & Styer 1969; Krantz 1973; Easterbrook 1978; Bergh & McCoy 1997; Zhao & Amrine 1997). Phytoseiidae have been reported to disperse aerially on strawberries (Coop & Croft 1995) and in vineyards (Tixier et al. 1998, 2000). Tetranychidae disperse aerially from peach and maize (Margolies 1995), maize (Margolies & Kennedy 1985; Margolies 1987; Smitley & Kennedy 1988) and apples (Margolies 1995, Larson et al. 1996). No studies have been conducted on the dispersal mechanisms of Tydeidae. However, it appears that the dispersal of *L. formosa* is similar to the families mentioned above.

Tydeus californicus has been reported as an abundant tydeid species in Israel and Spain (Gerson 1971; García-Marí et al. 1985) and in California (Quayle 1912; McGregor 1956), but it was found in low numbers in the 1995-1996 survey in Florida. Certain environmental conditions apparently influence the abundance of *T. californicus*, because numbers collected in Florida in 1995 were very low compared with densities observed in

1998 and 1999. In some of the orchards sampled, especially Hart II, numerous gravid females were observed carrying large numbers of eggs during the summer months. This suggests dispersal by this tydeid species since the conditions in that orchard appeared to be inappropriate for mite development. *Tydeus californicus* is an ovoviviparous mite (Fleschner and Arakawa 1952, Castagnoli 1984).

Rizk et al. (1978-1979b) found *T. californicus* to be one of the most abundant mites on orange trees in a survey conducted in the Minia region of Egypt. *Tydeus californicus* peaked on leaves in June 1975 with about 13 mites per leaf. These authors also determined that *T. californicus* was the most abundant on lemon trees with about 14 mites per leaf, between May and June 1975.

In our study, T. *munsteri* was more abundant in orchards with a history of herbicide application, such as in Yarborough, Mixon I and Mixon II (see Table 3-1). *T. munsteri* was present in most citrus habitats in Mixon I, where *L. formosa* densities were low, compared to the orchards in Polk and Lake counties. *T. munsteri* represented only 5% of the total tydeid fauna found in Mixon I. Its distribution is not well known since it was collected from *Citrus limonia* Osbeck, *Erythrina caffra* Thunberg, and *Psidium guajava* L., and only from South Africa (Meyer & Ryke 1959; Meyer 1998). In the present study, *T. munsteri* was recovered on leaves, fruit, and tree trunk brushings from four Florida orchards, i.e., Yarborough, Hart II, Mixon I and II from April to May, and again in October 1995 and January 1996.

Tydeus gloveri was found mostly on leaves in all sites except in Yarborough, while *P. mumai* was collected from all the orchards, mainly on leaves. Both species were also collected from other habitats, e.g., twigs and fruit but in lower numbers. The

seasonal occurrence of both *T. gloveri* and *P. mumai* were similar to *L. formosa.* Both species were less abundant during July to October when the populations of *L. formosa* occurred in lower numbers too.

McMurtry et al. (1970) found many phytoseiids at the junctions of veins on the lower surfaces of leaves that lacked domatia and observed that some phytoseiids preferred sheltered locations for oviposition. Similar behavior was observed for certain tydeids on citrus, especially with *L. formosa* and *T. californicus*. Since citrus leaves lack domatia, junctions of veins, leaf irregularities and buds might serve as shelters for tydeid mites. All stages of *L. formosa* and *T. californicus* were generally found in aggregations along the veins, especially the midribs of the lower leaf surface, as well as on twigs and at the base of the leaf petioles.

Muma (1975) conducted surveys during the 1950s and 1960s and did not identify *L. formosa* as a component of the tydeid fauna on Florida citrus. However, he found *L. floridensis* and *L. marcandrei* on leaves, and *L.* sp. near *bedfordensis* in citrus litter. Muma (1975) neither indicated the time of the year when they were most abundant nor the citrus cultivars from which they were collected. None of these species were found in these surveys.

André (1983,1986) described several micro-habitats where bark mites dwell, including epiphytic plants. In these surveys, the mites were brushed off the main tree trunks without considering any of the micro-habitats defined by André (1983,1986). The *Apopronematus* species that were found on citrus bark in Florida was previously undescribed. *Apopronematus bakeri* André is a monotypic species described by André (1980) on grape bark from a single vineyard in Napa Valley, California. Significant

differences exist between this and the new species found in Florida. Populations of *Apopronematus* sp. in this survey were found only in orchards where herbicides were not used. The same situation exists with *P. shawi*, the other bark dwelling species recovered from this survey. Muma (1975) collected *P. shawi* from bark on citrus, but his studies did not sample other microhabitats. André (1986) discussed micro-habitats that included: foliose, crustose and fruticose epiphytes.

Metapronematus leucohippeus Treat, was a monotypic species described from the external tympanic recesses of moths by Treat (1970). A new species of *Metapronematus* was found inhabiting twigs, outer leaves, and immature citrus fruit at Yarborough and Hart II in May and July and from Mixon I in January 1996. *Metapronematus* sp. was also found on several ground cover plants, i.e., *R. hastatulus* in March, *C. retrorsus,* in April, *E. fosbergi*, *C. hirta* and *P. texanum* in May, *H. subaxillaris*, in July, and *C. hyssopifolia* in November. Its role in nature is unknown.

Parapronematus acaciae was found in relatively low densities in Pollard, Hart I and II. At Mixon I, it occurred in considerable frequencies of 22, 16 and 13% on outer leaves, mature fruit, and immature fruit, respectively. *Parapronematus acaciae* was considered one of the most common tydeid species found on Florida citrus in the 1960s based on the reported densities occurring in citrus orchards throughout the state especially in January or February or June and July (McCoy et al. 1969; Muma 1975).

Pseudolorryia mumai was collected from citrus plant micro-habitats in low densities from citrus orchards where insecticides and/or acaricides were applied (i.e., Trask and Yarborough). The highest numbers of *P. mumai* were found in Mixon I and II where herbicides were used. The frequency of *L. formosa* was considerably reduced at

Mixon I and II compared with the frequencies found in the other 5 orchards. Therefore, species such as *P. mumai*, appear to occupy the same niches within the citrus tree as *L. formosa* in orchards free of ground cover plants.

In the present study, *L. formosa*, *P. mumai*, *T. gloveri*, *T. munsteri*, *P. acaciae*, and *Metapronematus* sp. were identified from ground cover plants collected throughout the year. There are no studies reporting tydeids on ground cover plants associated with specific commodities. Brown et al. (1997) found that the use of ground cover species had minimal effect on apple production in a study with mature apple trees in West Virginia, USA. For other authors, however, the use of ground cover plants could enhance the impact of natural enemies on pest arthropods, since they might serve as reservoir sites for predatory organisms and parasitoids (Du & Yan 1995). The actual effect of tydeid mites on ground cover plants associated with citrus should be determined.

In summary, it was observed that the tydeid species found in this survey showed similar trends in their seasonal occurrences with *L. formosa*, in most cases, being the prevalent species. Tydeid species were more abundant on inner and outer leaves, and *L. formosa* showed the highest densities in both habitats. Tydeids were found throughout the year, although they were more abundant, in most cases, between April and May.

In the Trask orchard, *L. formosa* was found in higher numbers, with almost 400,000 estimated mites. *Tydeus gloveri* was second with 59,000 mites. These two species comprised 98.5% of the total Tydeidae population in this site. *Paralorryia shawi*, *P. mumai*, *T. californicus*, and *Apopronematus* sp. were the other species collected in Trask, comprising 1.5% of the population. *Lorryia formosa* populations on inner and

outer leaves showed statistical differences in February and May, being higher on inner leaves.

In Yarborough, *L. formosa* was the prevalent species, with a frequency of 97% of the estimated tydeid population. *Tydeus munsteri* was the second most abundant species with a frequency of 2.5%, and *P. acaciae* was third. *Paralorryia shawi*, *P. mumai*, *Apopronematus* sp., and *Metapronematus* sp. were collected in reduced numbers. Neither *T. californicus* nor *T. gloveri* were collected in this orchard. *Lorryia formosa* populations were significantly higher on inner leaves during April and May.

The highest *L. formosa* numbers of all sites were recorded in the Pollard orchard, with 433,000 mites, comprising 98.5% of the total population. *Tydeus gloveri* was second with 4,558 mites and a frequency of 1%, and *P. mumai* reached 1,293 for 0.5%. *Paralorryia shawi*, *Apopronematus* sp., and *P. acaciae* were found in low numbers. Statistical difference between leaf habitats were determined for January 1995 with *L. formosa* densities being higher on inner leaves.

Populations of *L. formosa* were high in Hart I, with a total of 325,000 mites and a frequency of 97%. *Tydeus gloveri* was second in number with about 9,000 mites and 2.5% of the total, whereas *T. californicus* was the third species in importance with 1,655 mites and a frequency of 0.5%. *Pseudolorryia mumai* and *P. acaciae* were the other two tydeid species collected in Hart I, but in low numbers. Statistical differences between leaf habitats occurred in March and July, with *L. formosa* being more abundant on inner leaves in March and outer leaves in July.

In Hart II, *L. formosa* was the prevalent species with a frequency of 97% although in lower numbers compared with the 4 sites already summarized. *Pseudolorryia mumai*

was second with a frequency of 3%. *Tydeus gloveri*, *T. munsteri*, *Metapronematus* sp., and *P. acaciae* were collected in low numbers. This orchard had more sampling dates with statistical differences between inner and outer leaves. Higher densities of *L. formosa* occurred in February, March, May, July, October, and November 1995 and January 1996 on inner leaves.

Lorryia formosa was the prevalent species in the Mixon I orchard, with a frequency of 65%. The *L. formosa* numbers were reduced compared with the orchards in Polk and Lake counties. *Pseudolorryia mumai* was second in importance with a frequency of 20%. *Parapronematus acaciae* and *P. mumai* had frequencies of 8 and 5 %, respectively. *Tydeus gloveri* had a frequency of 2%. *Paralorryia shawi* and *Metapronematus* sp. were found in low numbers.

In Mixon II orchard, *L. formosa* was the prevalent species with a frequency of 67%, similar to Mixon I. *Parapronematus acaciae* was second with a frequency of 13%. *Tydeus gloveri* and *P. mumai* followed with frequencies of 10 and 9%, respectively. *Tydeus munsteri* had a frequency of 1%.

Overall, the common factor in all the sites was the prevalence of *L. formosa* although occurring in lower relative numbers in the Mixon I and II orchards. *Tydeus gloveri* was the second most abundant species. *Pseudolorryia mumai* was collected from all the sites, although in reduced numbers with the exception of the Mixon orchards. *Tydeus californicus* was collected from only two sites during this survey, whereas *P. acaciae* was found in six of seven orchards but in reduced frequencies, with the exception of the Mixon orchards. *Tydeus munsteri*, *P. shawi*, *Apopronematus* sp., and *Metapronematus* sp. were found in low frequencies in this survey.

Tydeid mites may play an important role in maintaining a balance between phytophagous mites and predators that has implications for integrated control programs (Castagnoli & Liguori 1987; Childers 1994). The major component of the tydeid fauna on Florida citrus was *L. formosa*, whose densities at times exceeded 200 mites per leaf. Therefore, the potential multiple roles of tydeids as predators, fungal feeders or secondary sources of food for predacious arthropods must be assessed to effectively develop an integrated mite and disease management program on citrus.

CHAPTER 5
FEEDING HABITS OF THE TYDEIDAE ASSOCIATED WITH CITRUS IN FLORIDA

Introduction

The range of habitats of Tydeidae is remarkable and includes fungi, stored grains, plant litter, mosses, and numerous types of plants, such as shrubs, herbaceous species, and trees (Krantz 1986). Their ecological roles and food habits are mostly unconfirmed (Hessein & Perring 1986).

Several tydeid species have been found on citrus worldwide, but little is known about their food preferences. For instance, *L. formosa*, a common tydeid found on citrus throughout Florida, was considered a phytophagous species causing damage to citrus trees in Morocco (Smirnoff 1957, 1959). Del Rivero (1962-1963) stated that *L. formosa* caused significant damage to citrus trees in Spain and it was reported damaging green twigs and young fruit of citrus in Morocco and Brazil (Smirnoff 1957, 1959; Flechtmann 1973). Smirnoff (1957, 1959) observed that *L. formosa* numbers were correlated with the abundance of honeydew from feeding stages of an unidentified scale insect. Honeydew was one food source for tydeids identified by Benfatto (1980) and García-Marí et al. (1985) on citrus.

According to Thoreau-Pierre (1977), feeding by *L. formosa* occurred on animal detritus, especially chitin on citrus in Algeria. Mendel and Gerson (1982) considered this species to be a sanitizing agent on citrus trees in Israel, since the mites fed on sooty mold, which contaminated citrus leaves and fruit, and on honeydew

excreted by *S. oleae*. Inserra (1967) reported *L. formosa* to be associated with another coccid scale, *Ceroplastes sinensis* Del Guercio.

The feeding habits of other tydeid species found on citrus have received little attention compared to those of *L. formosa* and reports found in the literature are mostly based on field observations. For example, *T. californicus* was reported by Baker and Wharton (1952) as a predator of the citrus bud mite, *A. sheldoni*, and as being phytophagous by Fleschner and Arakawa (1952) and Zaher and Shehata (1963).

Tydeus gloveri was reported to be associated with the purple scale, *L. beckii*, on citrus in Florida, supposedly feeding on their eggs (Ashmead 1879). Dead organic matter, honeydew, and fungi all served as food sources for *T. gloveri* according to Muma (1975). McCoy et al. (1969) reported that *P. acaciae* fed on *P. digitatum* and *C. gloeosporioides*, two commonly found leaf inhabiting fungi on citrus trees.

A series of experiments was conducted to determine the feeding behavior of selected species of Tydeidae previously identified on citrus.

Materials and Methods

Observational studies- Grapefruit leaves were selected as experimental units to observe tydeid feeding behavior. The leaves were healthy, mature, and fully expanded to 12.7 x 6.3 cm. Leaves were washed in a solution of water and 2% sodium hypochlorite, and then cleaned with a brush to eliminate detritus and the remains of insects and mites before use. The units were modified from a leaf arena designed by Abou-Setta and Childers (1987) to rear phytoseiid and tetranychid mites. The leaves, one per unit, were placed lower side up on a photographic cotton sheet (Webril® wipes, BBA Nonwovens,

Walpole, MA), placed on a de-ionized water-saturated polystyrene pad in a 135 mm diam. Petri dish (Fisherbrand®, Fisher Scientific, Suwanee, GA) bottom filled with de-ionized water.

Material taken directly from the field and studied in the laboratory.

Studies were conducted with the following species: *Lorryia formosa*, *Tydeus californicus*, *T. gloveri*, *Pseudolorryia mumai*, and *Parapronematus acaciae*. Grapefruit and orange leaves were collected from several orchards to determine whether specific tydeid species would feed on specific organisms, e.g., other mites, other arthropods, their waste products, remains, or fungi. Samples were returned to the laboratory, and then photographed. Tydeids present on leaves were observed each time a field collection was conducted with a stereoscopic microscope. Adult tydeids were then transferred to new leaves to study their responses to different potential food sources. These studies were conducted from 1996 to 2001.

Rearing of tydeid mites using artificial diet.

Information on appropriate diets for rearing tydeid mites is lacking. Therefore, the following food sources were supplied to observe whether each tydeid species would feed, oviposit and produce viable eggs: sugar water (sucrose, ultracentrifugation grade, FisherBiotech®, Fisher Scientific, Fairlawn, NJ), ice plant pollen (*Malephora crocea* Jacques), or a combination of both food sources. These studies were conducted during 1996.

Pollen as a possible food source for *Lorryia formosa.*

Three types of pollen including ice plant, oak (*Quercus* sp.), and cattail (*Typha domingensis*) were offered singly to *L. formosa* on 14 October 2000. Particles of pollen collected on the tip of a spatula were deposited on the leaf arena substrate. The ice plant pollen was obtained from a commercial supplier located in Riverside, California. The oak and cattail pollens were collected from the CREC campus, and along the shores of local lakes in Lake Alfred, Polk County, respectively. The same type of arena, as described above, was used to complete the experiments, but each leaf was divided into three approximately 7 cm^2 sections. Females were starved for 48 h in a separate arena prior to initiation of each experiment replicate. Five tydeid females of the same species were then placed in one cell using a 5-0 sable brush and observed individually for 10 minutes, which was considered an appropriate and manageable time for Tydeidae. This process was repeated three different times for each pollen source. Once the third replicate was observed, the experiment was terminated. Observations were continued at different times over the following 3 days for each treatment replicate after the initial 10 minute continuous observations were completed. The studies were conducted in an environmental chamber at 25 °C, 60-80% RH and 14:10 L:D photoperiod.

Fungivory behavior of *Pseudolorryia mumai* and *Parapronematus acaciae.*

Small 'Valencia' orange fruits about 5 cm diam. with substantial densities of *P. mumai* and *P. acaciae* were collected during late November and early December 2000 in Winter Haven, Florida. The tydeids appeared to be feeding on *Colletotrichum* sp., that was present on the fruit surface. Development and hatching of the eggs were also

observed. Mites were maintained on the fungal-infested fruit and observations about their behavior and feeding responses were recorded once every other day for over six weeks. The fungus *Colletotrichum* sp. was identified by Dr. Sachindra Mondal (CREC, Lake Alfred, Florida) who cultivated the fungus in 5% water-agar in 80 mm diam. plastic Petri dishes immediately after returning the samples from the field. All subsequent experiments involving fungal material were identified by Dr. Mondal. *Colletotrichum* sp. was also offered to *L. formosa* to determine if the tydeid would feed on the fungus. All cultures were maintained at room temperature of 25 °C and approximately, 60-80% RH.

L. formosa and *P. acaciae* feeding on the fungal pathogen greasy spot, *Mycosphaerella citri* Whiteside.

An experiment was conducted to determine the behavior of *L. formosa* and *P. acaciae* when offered fungal mycelia of *M. citri*. Instead of leaves, 3 pieces of cardboard 2 x 2 cm each were used as the substrate. A pure culture of the fungal pathogen *M. citri* cultivated in 5 % water-agar in plastic Petri dishes was used on 25 October 2000. Three cardboard cells of 4 cm^2 each, contained either 5 *L. formosa* or 5 *P. acaciae* adults. *Lorryia formosa* or *P. acaciae* were previously held without food for 48 h and then transferred individually onto the test arenas using a 5-0 sable brush. Each cell was observed one at a time for 10 minutes immediately following introduction of the tydeid species. Three separate 10 minute observations (replicates) were completed for each of the two species and then the experiment was terminated. The arenas for each replicate were maintained in an environmental chamber at 25 °C, 60-80% RH, and 14:10 L:D photoperiod.

Feeding of *Lorryia formosa* on its own exuviae.

Thoreau-Pierre (1977) stated that *L. formosa* fed on its own exuviae, but he did not elaborate further. It was suspected that one or more microorganisms might be present on these exuviae. To determine what types of organisms could be present, leaf material was collected on 16 March 2001 from an abandoned 'Valencia' orange orchard located at Baseball City, Polk Co., Florida. Leaves were examined for the presence of *L. formosa* populations in the laboratory using a stereomicroscope. Small pieces of leaves with exuviae were cut and placed in a fixative of 3% glutaraldehyde in 0.1 M potassium phosphate buffer at pH 7.2 and held 4 h at room temperature. This procedure was followed to minimize cellular disruption. The material was then transferred to a post fixed 2% osmium tetroxide in 3% glutaraldehyde in a 0.1 M potassium phosphate buffer and held another 4 h at room temperature (Achor et al. 2001). Each sample was later dehydrated in ethanol and placed in a Ladd critical point drier using carbon dioxide as a carrier. A Hitachi S 530 scanning electron microscope was used to study and photograph the exuviae.

Predation studies- *Lorryia formosa* preying on *Aculops pelekassi* (PCRM).

Citron leaves cut into strips that were heavily infested with *A. pelekassi* were placed on grapefruit leaf arenas and held for 48 h to permit transfer and establishment of the mites. The infested grapefruit leaf arenas were used as the substrates for the experiment. The lower leaf surface was placed facing up on a piece of cotton soaked in de-ionized water and held in a Petri dish as reported previously. The leaf was divided into three cells (7 cm^2 each) using cotton strips in the same manner previously described.

Five *L. formosa* adults were placed in each of the three cells using a 5-0 sable brush and replicated 3 times for each of the following treatments:

1- same day (mites were taken directly from leaves collected in the orchard).

2- 24-hour starvation (mites were left in an arena without food for 24 h).

3- 48-hour starvation (mites were left for 48 h without food).

4- 72-hour starvation (mites were left for 72 h without food).

Lorryia formosa adults were placed in each treatment and observed constantly for 10 minutes immediately following infestation. Each of the cells, for all the treatments, was observed for 10 minutes, doing one at a time, and their behavior and responses to the food source(s) were recorded, using a stereoscopic microscope at 40 x magnification. If attempted predation was not observed in each arena within 10 minutes immediately following mite introduction, the experiment was terminated. If consumption of eggs or motile stages of PCRM were observed, the time taken to do so following their introduction onto the arena was recorded. Ten minute observations, once a day, every 24 h were continued until the tydeids or the eriophyids died, which usually occurred within 5 days. The arenas were maintained in a plastic box 30 cm x 16 cm x 9 cm on a bench under ambient conditions in the laboratory that averaged 25 °C and 60-80% RH. These studies were conducted between 31 March 2001 and 4 April 2001.

On orange fruit

'Hamlin' orange fruit about 5 cm diam. and heavily infested with *A. pelekassi* were collected in an orchard near Lake Alfred, returned to the laboratory and used as a

prey source for *L. formosa*. Infested PCRM fruit were used in the experiment once it was verified that no other possible food sources were present on the fruit surfaces. Each test fruit was divided into three cells, 2 x 4 cm each, using cotton strips saturated with de-ionized water. Five *L. formosa* females previously starved for 144 h were placed in each cell using a 5-0 sable brush and replicated three times on the same fruit. Ten minute observations for each replicate, one at a time, were completed to determine whether *L. formosa* would feed on *A. pelekassi*. Feeding behavior of *L. formosa* was recorded and the experiment was considered terminated after finishing the three 10 minute continuous observations. Irregular 10 minute observations of each replicate were made at different times for 6 more days. This experiment was initiated on 16 May 2001 and observed until 22 May 2001.

Predation studies- *Lorryia formosa* preying on *Phyllocoptruta oleivora*.

Methods followed for these studies were the same used for PCRM. A grapefruit leaf was also used as the substrate. Five *L. formosa* adults, previously held without food for 48 h, were placed in each cell (3 replicates) using a 5-0 sable brush, all on the same leaf and each observed continuously for 10 minutes, doing one at a time. The behavior of *L. formosa* was recorded throughout each 10 minute interval and then each experiment was terminated. The arenas were placed in a plastic box 30 cm x 16 cm x 9 cm within an environmental chamber at 25 °C with 60-80% RH. This experiment was conducted on 1 November 2000.

Predation studies- *Lorryia formosa* preying on *Panonychus citri* eggs.

Methods followed for these studies were the same used for PCRM. *Panonychus citri* females were placed on each leaf arena for 48 h to obtain a cohort of eggs. The arenas were placed in a plastic container and maintained on a bench in the laboratory. Five *L. formosa* adults previously held without food for 48 h were placed in each cell using a 5-0 sable brush with 3 replicates (15 total). Each treatment replicate was observed continuously for 10 minutes immediately following transfer of the mites. The behavior of *L. formosa* was recorded continuously during each ten minute interval to determine if the mite would feed on *P. citri* eggs one cell at a time. Irregular observations were continued until *P. citri* reached the adult stage. Daily temperature averaged 25 °C with 60-80% RH. The experiment was initiated on 12 May 2001 and terminated on 22 May 2001.

Predation studies- *P. acaciae* preying on *P. oleivora*.

The procedures followed for these studies were the same used for PCRM. A grapefruit leaf was also used as the substrate. Five *P. acaciae* adults were placed in each of three cells on one leaf using a 5-0 sable brush. Each arena was observed separately for 10 minutes immediately after transfer of *P. acaciae* to the arena surface. The behavior of *P. acaciae* was recorded throughout each 10 minute interval and the experiment was then terminated. The arenas were placed in a plastic box 30 cm x 16 cm x 9 cm within an environment chamber at 25 °C with 60-80% RH. This experiment was conducted on 1 November, 2000.

Evaluation of *L. formosa* when offered multiple food types including: PCRM, ice plant pollen and sugar water.

The same methods were followed in these studies as were used with *L. formosa* with each individual type of food. A grapefruit leaf, lower side up, was also used as the substrate. Five *L. formosa* adults were placed in each of three cells (7 cm^2 each), on one leaf and separated by water saturated cotton strips, using a 5-0 sable brush. The three replications were observed for 10 minute intervals at separate times immediately following transfer. The behavior of *L. formosa* was recorded throughout each time interval to determine whether they would feed on either PCRM, ice plant pollen or sugar (sucrose) water or to determine a food preference. Mites were previously held on a leaf arena without food for 72 h. Irregular 10 minute observations were made at different times for 30 more days. The arenas were maintained in a plastic box 30 cm x 16 cm x 9 cm at room temperature averaging 25 °C with 60-80% RH. The experiment was initiated on 13 May 2001 and terminated on 14 June 2001.

Predation studies- *Tydeus gloveri* preying on *Aculops pelekassi* (PCRM).

The same methods were followed in these studies as were used with *L. formosa*. A grapefruit leaf, lower side up was also used as the substrate. Five *T. gloveri* adults were placed in each cell (7 cm^2 each) using a 5-0 sable brush and replicated three times. Each cell was observed for a 10 minute interval, one at a time. The behavior of *T. gloveri* was recorded throughout each time to determine if it would feed on PCRM and the experiment was then terminated. Mites were previously held on a leaf arena without food for 48 h. Irregular observations of 10 minute duration each were made at different times for 6 more days. The arenas were maintained in a plastic box 30 cm x 16 cm x 9 cm on a

bench at room temperature averaging 25 °C with 60-80% RH. The experiment was initiated on 16 May 2001 and terminated on 22 May 2001.

Predation studies- *Pseudolorryia mumai* preying on *Aculops pelekassi* (PCRM).

The same methods were followed in these studies as were used with *L. formosa* and *T. gloveri*. A grapefruit leaf was also used as the substrate. Five *P. mumai* females were placed in one of three cells using a 5-0 sable brush, and observed for 10 minutes. Upon completion, another cell was infested and the observation interval was repeated. The behavior of *P. mumai* was recorded for each of the three replications and the experiment was then terminated. Mites were held on an arena without food for 48 h. Irregular observations were made at different times for 30 more days. The arenas were maintained in a plastic container on a bench at room temperature averaging 25 °C with 60-80% RH. The experiment was initiated on 4 April 2001 and terminated on 4 May 2001.

Lorryia formosa on a glass surface without food.

A Petri dish bottom 80 mm diam. was divided into three cells, approximately 2 x 2 cm each in this study. Five tydeid females were placed in each cell using a 5-0 sable brush and replicated three times. Mites were individually observed daily to determine how long they would survive without food until the last female died. The culture was placed in a plastic container and maintained on a bench in the laboratory at room temperature of approximately 25 °C and 60-80% RH. The experiment was conducted between 12 May 2001 and 29 May 2001.

Results

Material taken directly from the field and studied in the laboratory.

The tydeid species collected from citrus were found, in most cases, associated with other organisms or detritus. For instance, *L. formosa* was observed forming colonies on the leaves or petioles, in the midst of detritus or associated with whiteflies (e.g., Woolly whitefly, *Aleurothrixus floccosus* [Maskell]) or scale insects (Homoptera: Diaspididae) (Figs. 5-1 A, B, C, D; 5-2 A). *Tydeus gloveri* females and eggs were found on 'Hamlin' orange leaves associated with detritus (Fig. 5-2 B). *Pseudolorryia mumai* and *P. acaciae* were also found in the field in association with *Colletotrichum* sp. (Figs. 5-2 C, D).

Rearing of tydeid mites using artificial diet.

When sugar (sucrose) water was offered, *L. formosa, T. californicus* and *T. gloveri* mites went directly to the food source and began feeding (Table 5-1). The mites spent an average of 5 minutes feeding on the source, laid eggs and the colony looked healthy. During a two week interval, adults, larvae, nymphs and quiescent stages were all observed on the substrate. After three weeks of observations, the colonies were eliminated.

When *L. formosa*, *T. californicus* and *T. gloveri* were transferred to arenas with ice plant pollen and sugar (sucrose) water, each tydeid species consumed both food sources. *L. formosa* and *T. gloveri* females began laying eggs along the midrib before feeding. *Tydeus californicus* gave birth to larvae and laid a few eggs before feeding. Mites formed small colonies on the leaf surface, especially along the midrib and

Fig. 5-1. (A) Photomicrograph of *Lorryia formosa* associated with detritus on a citrus leaf. (B) Photomicrograph of *L. formosa* associated with Woolly whitefly, *Aleurothrixus floccosus* (Maskell) (Homoptera: Aleyrodidae) on a citrus leaf. (C) Photomicrograph of *L. formosa* associated with either Snow scale, *Unaspis citri* (Comstock) or Purple scale, *Lepidosaphes beckii* (Newman) (Homoptera: Diaspididae) female on a citrus leaf. (D) Photomicrograph of *L. formosa* associated with *A. floccosus* nymphs on a citrus leaf.

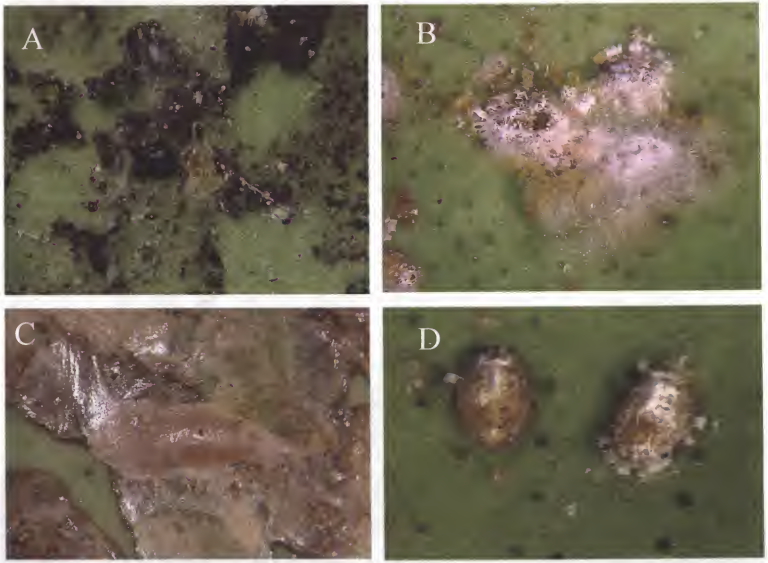
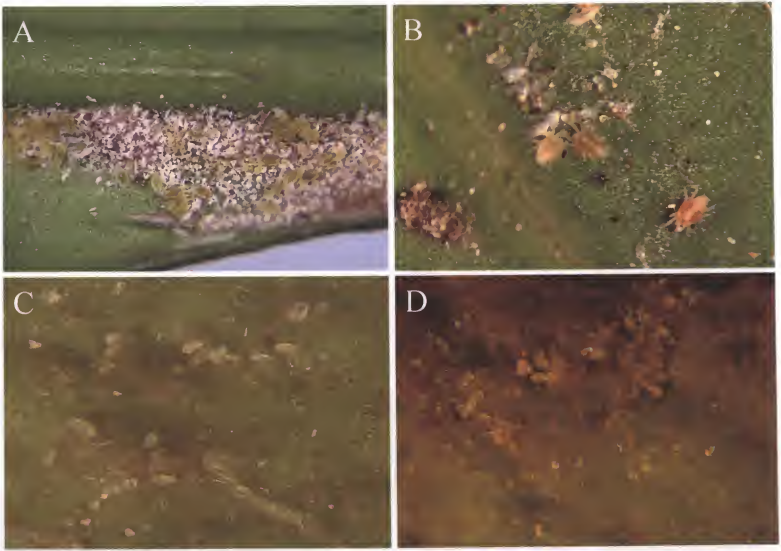

A
B
C
D

Fig. 5-2. (A) Photomicrograph of *Lorryia formosa* colony showing exuviae, eggs, quiescent and motile stages. (B) Photomicrograph of eggs and adults of *Tydeus gloveri* on a citrus leaf. (C) Photomicrograph of a colony of *Pseudolorryia mumai* and *Colletotrichum* sp. growing on a citrus immature fruit surface. (D) Photomicrograph of a colony of *P. mumai* and *Colletotrichum* sp. growing on a citrus immature fruit surface.


A
B
C
D

L. formosa, in particular, at the base of the lamina (Fig. 5-2 A). Adults, immatures and chrysalis stages were all found together and they also molted there with subsequent accumulation of the exuviae on the substrate. Populations of each tydeid species could be maintained for about a month and then each gradually decreased and was discarded.

The colony of *T. californicus* was started with 20 females and two days later, 31 larvae and 1 egg were observed on the substrate. After two more days, there were about 60 larvae and 5 eggs on the substrate. The mites were observed feeding before and after giving birth to live young.

Tydeus gloveri responded positively to diets of sugar (sucrose) water and ice plant pollen. The mites reproduced and laid eggs after feeding and were active during the first 4 weeks of the experiment. After that time, the colony decreased and only a few adults survived after three months.

Table 5-1. Response of three Tydeidae species to two diets.

Food offered	Tydeid species	Fed on food offered
sugar water (sucrose)	*L. formosa*	yes
sugar water (sucrose)	*T. californicus*	yes
sugar water (sucrose)	*T. gloveri*	yes
sugar water + ice plant pollen	*L. formosa*	yes
sugar water + ice plant pollen	*T. californicus*	yes
sugar water + ice plant pollen	*T. gloveri*	yes

Pollen as a possible source for *Lorryia formosa.*

Lorryia formosa fed on ice plant, cattail and oak pollens (Table 5-2). The shortest time from tydeid release to feeding was about a minute per pollen; more tydeids went to

ice plant pollen and soon after the encounter, the mites were observed carrying pollen particles on their bodies. During the 10 minute observation, there was a positive response

Table 5-2. Response of starved *L. formosa* females to three types of pollen in 10 minute observations.

Type of pollen	Replicate	No. females tested	Individual female	Time (in minutes) when females made first contact with pollen
ice plant	1	5	1	3
			2	3
			3	3
			4	9
			5	0
	2	5	1	1
			2	2
			3	2
			4	10
			5	0
	3	5	1	1
			2 to 5	0
cattail	1	5	1	2
			2	2
			3 to 5	0
	2	5	1 to 5	0
	3	5	1	1
			2	1
			3 to 5	0
oak	1	5	1 to 5	0
	2	5	1	1
			2	1
			3	5

Table 5-2 continued

		4	9
		5	0
3	5	1 to 5	0

towards the pollen in nine of the 15 mites tested in the experiment for ice plant pollen (Table 5-2). Four *L. formosa* females were observed feeding during the first ten minutes of evaluation on both cattail and oak pollens. The three cultures were maintained and observed for approximately 4 more days and the mites were still alive, appeared healthy and fed on the three pollen sources. All the mites had pollen particles attached to their bodies indicating they had made contact with the three pollen types. Although the tydeids were observed feeding on pollen, reproduction was not determined. The *L. formosa* population was able to survive for about three weeks when ice plant pollen only was provided.

Fungivory behavior of *Pseudolorryia mumai* and *Parapronematus acaciae.*

Pseudolorryia mumai and *P. acaciae* were found feeding and reproducing on a fungus growing on the surface of immature 'Valencia' oranges (Figs. 5-2 C, 5-2 D). The fungus was a non-pathogenic strain of *Colletotrichum* sp. (Mondal, S. 2000. Personal communication).

Both tydeid species, *P. mumai* and *P. acaciae,* fed on *Colletotrichum* sp. and oviposited in the crevices of the fruit. The *P. mumai* and *P. acaciae* colonies were maintained for about 6 weeks until the fruits began to decompose and were then discarded. Both species of tydeids were observed feeding on mycelia of *Colletotrichum* sp. and laid numerous eggs in depressions on the fruit surface or in areas where mycelia

occurred. *Colletotrichum* sp. was isolated, cultivated and later offered to *L. formosa*. Observations were made for 40 minutes and none of the mites were observed feeding on the fungus.

Tydeids were slide-mounted in Hoyer's medium (Krantz 1986) and fungal spores were evident within their digestive tracts. Four slides of *Tydeus californicus* had *Colletotrichum* sp. spores as well as *Penicillium* sp., and other non-identified fungi present in their digestive tracts. Seven slides of *Tydeus gloveri* had *Colletotrichum* sp. spores in their bodies while one slide of *L. formosa* had *Penicillium* sp. spores in its digestive tract; another had a *Colletotrichum* sp. One slide preparation of *L. formosa* collected in Morocco had a fungus identified as *Penicillium* sp., and four slides of *L. formosa* collected in Portugal had spores of *Penicillium* sp. and *Colletotrichum* sp. present within their digestive tracts.

L. formosa and *P. acaciae* feeding on the fungal pathogen greasy spot, *Mycosphaerella citri*.

M. citri mycelia were offered to *P. acaciae* and *L. formosa*, but no feeding responses were observed. Both tydeid species did not appear to feed on this pathogen (Table 5-3). Only a few mites stopped and probed the substrate, but did not feed. After two days all the mites were missing from the test arenas.

Table 5-3. Response of starved *L. formosa* and *P. acaciae* females to the fungal pathogen greasy spot, *M. citri*.

Tydeid species	**No. females tested (3 replicates combined)**	**No. females feeding on *M. citri***
L. formosa	15	0
P. acaciae	15	0

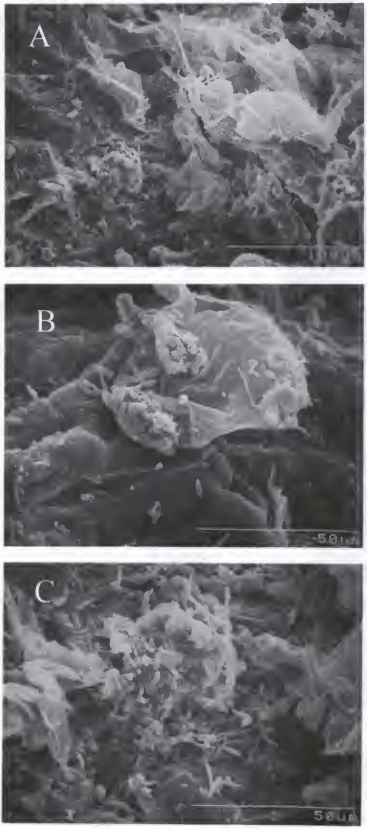
Feeding of *Lorryia formosa* on its own exuviae.

The exuviae were full of spores released by a *Colletotrichum* type of fungus and unidentified bacteria that served as food sources for *L. formosa* (Fig. 5-3 A, B, C).

Predation studies- *Lorryia formosa* preying on *Aculops pelekassi* (PCRM).

Individual *L. formosa* moved around the cell and occasionally probed the substrate. *Lorryia formosa* females approached PCRM adults and attempted to feed but they were left after a few moments of struggle. *Lorryia formosa* also attempted to feed on PCRM larvae and eggs and were succesful (Table 5-4). From all the attempts of feeding made by *L. formosa*, seven failed, four on PCRM adults and three on immatures (Table 5-4). Twenty three attempts to feed on PCRM immatures (eggs and motile stages) by *L. formosa* females were successful. In total, 75 females were used in this experiment. On some occasions, an *L. formosa* female attacked more than one PCRM within the 10 minute observation period. For instance, a female observed after 48 h of starvation, fed on three immatures during the 10 minute observation period and, after that, fed on one more within 1 minute. After 72 h of starvation, a female was observed feeding on three eggs within the 10 minute observation interval. Feeding on PCRM by *L. formosa* is difficult to observe since the tydeid usually covers its prey with its body. The tydeid does not move during the process of inserting its chelicerae into the prey and then removing the body contents of the PCRM stage. However, the body of the prey becomes deflated as proof of feeding. The feeding intervals were variable and lasted an average of

Fig. 5-3 (A), (B), (C). Fungal mycelia, *Colletotrichum* sp. spores, and bacteria growing on *Lorryia formosa* exuviae.


A
B
50um
C
50um

6.19 minutes (± 4.10 minutes SD) for motile immature stages, based on 16 observations and 2.14 minutes (± 0.38 minutes) for eggs, based on 7 observations (Table 5-4). The duration of feeding per individual female is indicated in Table 5-4.

Four *L. formosa* females attempted to feed on different adult PCRM but each stopped after a few minutes. The cuticle may be too hard or too thick for the tydeid's chelicerae to effectively penetrate. *Lorryia formosa* females were unable to succesfully feed on adult PCRM.

The predacious nature of *L. formosa* on *A. pelekassi* was first evaluated after a 48 h starvation interval. The experiment was repeated at a range of starvation intervals: 0 h, 24 h, and 72 h on leaves and 144 h on fruit. *Lorryia formosa* preyed on PCRM regardless of whether they had been starved or not. After a 72 h starvation interval, one *L. formosa* female was observed consuming three PCRM eggs, one after the other and each feeding interval required 2 minutes. On 'Hamlin' orange fruit, *L. formosa* attacked *A. pelekassi* 3 minutes after the experiment began and the feeding interval lasted 2 min in consuming a PCRM immature (Table 5-4). The same behavior described for leaves was observed on fruit. The percentages of successful consumption for each starvation time were as follows: 6.7% of *L. formosa* females fed on *A. pelekassi* eggs and immatures at 0 h, 0% at 24 h, 40% at 48 h, 40% at 72 h, and 13% at 144 h on fruit. *Lorryia formosa* females were observed consuming PCRM immatures and eggs for hours after the experimental intervals were terminated. *Lorryia formosa* finds its prey by moving its pedipalps and first pair of legs up and down as it walks and touches the substrate until a prey is found. This tydeid then seizes and holds the prey followed by insertion of the chelicerae into the eriophyid's body, which is usually through the propodosoma or opisthosoma. *Lorryia*

formosa supports its legs on the substrate and remains still (Figs. 5-4 B, C). Once the prey is seized, the tydeid begins feeding on the internal contents leaving only the shriveled carcus on the substrate after all body fluid contents have been consumed. The *L. formosa* adult then moves and seeks another prey and repeats this behavior. When the PCRM is relatively large (i.e., nymph or adult) the eriophyid tries to escape by moving its body. However, in the case of PCRM immatures (i.e., mostly larvae), *L. formosa* holds the prey firmly and once the immature prey is caught it is difficult to escape.

When *L. formosa* completed consuming its prey, it moved its own body in circles for several seconds palping the substrate. It appeared that *L. formosa* is trying to locate the next prey near the site where the last one was consumed. This observation was repeated every time *L. formosa* fed.

The experiment was terminated when an unidentified fungus attacked the eriophyids four days after it began, starting with those located nearest to the wet cotton.

Table 5-4. Predation by *L. formosa* females on *A. pelekassi, P. oleivora,* and *P. citri* in a 10 minute observation.

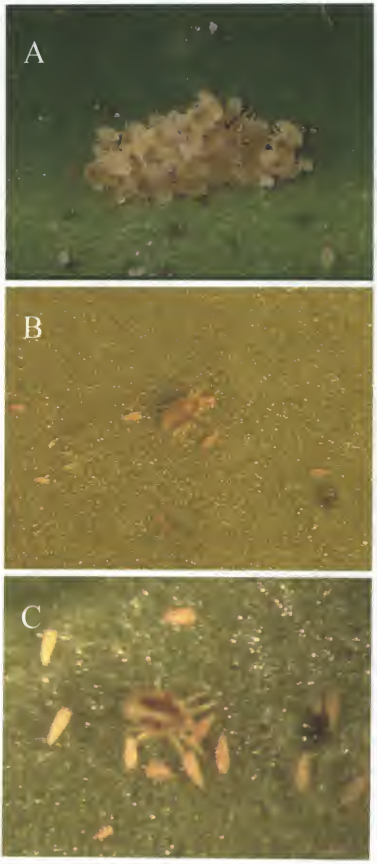
Prey offered	Starvation time in hours	Replication	No. females tested	Individual female	No. attempts of feeding	No. successes (**)	PCRM stage attacked
A. pelekassi	0	1	5	1	1	0	adult
				2	1	1 (5)	immature
				3 to 5	0	-	
		2	5	1 to 5	0	0	
		3	5	1 to 5	0	0	
	24	1	5	1 to 5	0	0	
		2	5	1	1	0	immature
				2 to 5	0	-	
		3	5	1 to 5	0	0	
	48	1	5	1 to 5	0	0	
		2	5	1	1	1 (10)	immature
				2	1	1 (5)	immature
					1	1 (13)***	immature
				3	1	1 (4)	immature
					1	1 (2)	immature
					1	1 (5)	immature
					1	1 (17)***	immature
				4	1	1 (6)	immature
				5	1	1 (9)	immature
		3	5	1	1	1 (4)	immature
					1	1 (3)	immature
				2	1	0	adult
				3 to 5	0	-	
	72	1	5	1	1	1 (5)	immature
				2	1	1 (2)	egg
					1	1 (2)	egg
				3	1	1 (2)	egg

Table 5-4 continued

				4	1	0	adult
				5	0	-	
		2	5	1	1	1 (2)	egg
				2	1	0	immature
				3	1	1 (2)	egg
				4 to 5	0	-	
		3	5	1	1	1 (4)	immature
					1	1 (5)	immature
					1	1 (3)	egg
				2 to 5	0	-	
	144*	1	5	1	1	1 (2)	immature
				2 to 5	0	-	
		2	5	1	1	1 (2)	egg
				2 to 5	0	-	
		3	5	1	1	0	adult
				2	1	0	immature
				3 to 5	0	-	
P. oleivora	48	1	5	1 to 5	0	0	
		2	5	1 to 5	0	0	
		3	5	1 to 5	0	0	
	48*	1	5	1 to 5	0	0	
		2	5	1 to 5	0	0	
		3	5	1 to 5	0	0	
P. citri	48	1	5	1 to 5	0	0	
		2	5	1 to 5	0	0	
		3	5	1 to 5	0	0	

*Fruit
** Time spent (in minutes) consuming each prey is indicated in parenthesis
*** Feeding interval was followed to completion

Fig. 5-4. (A) Photomicrograph of aggregation of all stages of *Lorryia formosa* on a citrus leaf. (B) Photomicrograph of *L. formosa* adult female feeding on *Aculops pelekassi*. (C) Photomicrograph of *L. formosa* adult female feeding on *A. pelekassi*.


A
B
C

Predation studies- *Lorryia formosa* preying on *Phyllocoptruta oleivora*

Phyllocoptruta oleivora was offered to *L. formosa* both on fruit and grapefruit leaves. No attempts of feeding on *P. oleivora* by *L. formosa* were observed during each 10 minute interval. The mites appeared to ignore *P. oleivora* and even shared the same areas of resting such as the natural concavities on the fruit surface. CRM usually rested, molted or oviposited in these same sites (Table 5-4). After the established 10 minute observations, the experiment was observed for one more hour to follow the behavior of *L. formosa* and no attempts of attacking *P. oleivora* were observed.

Predation studies- *Lorryia formosa* preying on *Panonychus citri* eggs

During each 10 minute observation, no attempts of feeding upon the eggs of *P. citri* were observed (Table 5-4). *Panonychus citri* eggs remained in the cells until hatching and the experiment was checked daily until the last spider mite reached the adult stage. No attempt to attack any of the tetranychid stages was observed by *L. formosa* during the 10 day interval of this experiment. Water was never a limiting factor for tydeid development since the cotton borders of the cells always remained wet.

Predation studies- *P. acaciae* preying on *P. oleivora*

No attempts of preying on *P. oleivora* were observed by *P. acaciae* in any of the three replications. *Parapronematus acaciae* actively explored the cells but did not try to feed upon *P. oleivora* (Table 5-5).

Table 5-5. Response of *P. acaciae* preying on *P. oleivora*.

Prey offered	No. females tested	No. females that fed
P. oleivora	15	0

Evaluation of *L. formosa* when offered multiple food types including: PCRM, ice plant pollen and sugar water

Once the *L. formosa* females were introduced into the cells, 5 of the 15 tydeids went directly to the sugar water. Feeding intervals on the sugar (sucrose) water lasted from 8 to 20 minutes (Table 5-6). One mite also went to the pollen source. None of the *L. formosa* adults were observed feeding on PCRM during the 10 minute observation

Table 5-6. Simultaneous exposure to three types of food offered to starved *L. formosa* and observed for 10 minutes.

Source of food offered	Replicate	No. females tested per replicate (total)	No. of attempts	No. of successes
ice plant pollen	1	5	0	0
sugar water	1		4	4
A. pelekassi	1		1	0
ice plant pollen	2	5	1	1
sugar water	2		2	2
A. pelekassi	2		0	0
ice plant pollen	3	5	0	0
sugar water	3		4	4
A. pelekassi	3		0	0

intervals (Table 5-6). *Lorryia formosa* explored the confined cells and made contact with the sugar water and pollen during subsequent observations after each 10 minute interval. Feeding on PCRM was not observed. Two days later, the *L. formosa* females began laying eggs. One month later, the *L. formosa* progeny were active and living in colonies along the midrib, even though none of the initial sources of food were supplied again. The original food sources were left on the substrate and the three types of food were attacked by an unidentified fungus. Bacteria could be present but were not evaluated.

Predation studies- *Tydeus gloveri* preying on *Aculops pelekassi* (PCRM).

The experiment was conducted for *T. gloveri* and no attempts to feed on PCRM were observed during the 10 minute observation intervals (Table 5-7). Six days after the experiment began, the PCRM population was attacked by an unidentified fungus and gradually disappeared. However, it was not determined whether the fungus was pathogenic or saprophytic. The *T. gloveri* population remained in good condition during each extended observational period, even though they never attempted to feed on PCRM.

Table 5-7. Response of *T. gloveri* and *P. mumai* preying on *A. pelekassi*.

Prey offered	No. females tested	No. females observed feeding
A. pelekassi	15 *T. gloveri*	0
A. pelekassi	15 *P. mumai*	0

Predation studies- *Pseudolorryia mumai* preying on *Aculops pelekassi* (PCRM).

Aculops pelekassi was offered to *P. mumai* and after three 10 minute observation intervals, there was no evidence that *P. mumai* attempted to feed on any PCRM stages (Table 5-7). However, *P. mumai* laid eggs and the active larvae were observed on the substrate 6 days later. Twenty days after the experiment began, the last *P. mumai* adult

died in the test arena. Although there was no evidence of feeding on PCRM by this species, apparent probing of the leaf tissue was observed.

Lorryia formosa on a glass surface without food.

The last of 15 *Lorryia formosa* females survived without food for 17 days with only water available on the cotton borders (Table 5-8). Three or four eggs were laid and hatched later. However, the larvae did not survive and died within 24 h after eclosion. When *L. formosa* females were left on leaves with no food, they managed to survive for much longer periods of time, suggesting that they were able to feed on leaf tissue or surface contaminants, although no evidence of damage was observed.

Table 5-8. *Lorryia formosa* survival on a glass surface without food.

Days of observation	Females surviving
Day 1	15
Day 3	13
Day 5	13
Day 7	11
Day 9	10
Day 11	9
Day 13	1
Day 15	1
Day 17	0

Discussion

Of the tydeids studied in the field and in the laboratory, *L. formosa* was the species of major focus, although, *T. californicus*, *T. gloveri*, *P. mumai*, and *P. acaciae* were evaluated. *Lorryia formosa* was found on leaves, twigs and branches forming aggregations along the midribs of the leaves, petioles, and buds. *Lorryia formosa* was found associated with other organisms such as scale insects, whiteflies, and living in areas of the leaves covered with debris, including the silken webs produced by psocopterans, as well as around empty scale shells. The association of *L. ferulus* and *T. bakeri* with scales was reported by Brickhill (1958), who studied the biology and feeding habits of *L. ferulus* and *T. bakeri* in California, both found in association with coccid scales. *Lorryia ferulus* was found closely related with *Lecanium quercitronis* Fitch, *L. pruinosum* Coquillet, *L. corni* Bouché, *L. cerasorum* Cockerell, *S. hemisphaerica* and *S. oleae*. *Tydeus bakeri* was found with *S. hemisphaerica*.

Lorryia formosa was described by Cooreman (1958) from material collected on citrus in Morocco and considered it a pest on citrus in that country (Smirnoff 1957,1959). Feeding injury described by Smirnoff included premature hardening and cracking of the green branches. When the mite was concentrated in the area between the sepals and fruit, it reportedly fed on the tissue of young fruit although this was not confirmed by experimentation. A maroon or dark zone reportedly developed as the fruit matured, resulting in damage resembling that produced by some thrips (Del Rivero 1962-1963). Similar damage was reported by Flechtmann (1973) in Brazil, who suggested that this tydeid sporadically exhibited phytophagous behavior.

Del Rivero (1962-1963) found large colonies of *L. formosa* associated with citrus in Spain and recommended control based on mite densities and previous reports by Smirnoff in North Africa. He also mentioned, based on Smirnoff's descriptions, several damage symptoms attributed to this species including premature sclerification of the green branches, followed by a peeling off in the form of scales on the spots where *L. formosa* concentrated. A ring of dead brown tissue was described on fruit that enlarged as the fruit grew. Del Rivero (1962-1963) believed that defoliation resulted from *L. formosa* infestations. Inserra (1967) made an extensive description of *L. formosa* and presented data about its biology, feeding habits, and distribution on citrus in Sicily, Italy. He corroborated that *L. formosa* was feeding on honeydew excreted by *S. oleae*, which was a common inhabitant of citrus in Italy.

Tydeus gloveri females appeared to occupy a similar substrate as *L. formosa* since they were found on leaves associated with detritus, and were laying eggs, which were deposited along the midrib, in a similar fashion as *L. formosa*'s. These two species appear to share some of the same habitats. *Tydeus gloveri* was described by Ashmead (1879) as *Acarus gloverii*, n.sp. (Glover's White or Yellow Orange Mite). He found it reported by Glover in an 1855 Agricultural Report. *Tydeus gloveri* was widely distributed throughout Florida and found in association with the purple scale, *L. beckii* on citrus, supposedly feeding on the eggs of this insect (Ashmead 1879).

Dead organic matter, honeydew, and fungi all served as food sources for *T. gloveri*, according to personal observations by Muma (1975). Baker (1970) mentioned that this was a common tydeid on citrus leaves in Florida, but he did not mention when and where this species was found within the trees. *Tydeus gloveri* also has been collected

on citrus leaves in Matamoros, Mexico and from Brownsville, Texas, from material confiscated by quarantine officers (Baker 1970).

Based on preliminary observations, it was determined that a 10 minute interval was a manageable time for studying the feeding behavior of *L. formosa*, *T. californicus*, and *T. gloveri*, since they usually spend a few minutes exploring the arena surface until they stop and probe the substrate or feed. This behavior differed from that of starved phytoseiids, which usually attacked their prey within a few seconds after exposure. This behavior has been observed in *N. fallacis* under laboratory conditions when *T. urticae* stages were offered as prey on artificial arenas in studies conducted at Washington State University, Pullman, Washington, between 1993 and 1994 (Personal observation).

Ice plant pollen was found to be a suitable food source for *L. formosa*, *T. gloveri*, and *T. californicus* although pollen was considered just a component of a more complex diet. *Tydeus californicus* is an ovoviviparous species according to observations by Fleschner and Arakawa (1952), Soliman et al. (1974), Castagnoli (1984), and Castagnoli et al. (1984). Rearing studies conducted here confirmed their observations. Lindquist (1998) stated that the ovoviviparity seems to be linked primarily to parasitic, parasitoid or predatory mites having a close and necessarily synchronous association with insects that undergo relatively rapid development, e.g. *Varroa* associated with *Apis*, *Pyemotes* associated with subcortical beetles or *Macrocheles* spp. associated with dung-inhabiting insects. Since *T. californicus* is a species with no obligate association with any insect, the causes of its ovoviviparity are unknown. The feeding habits of *T. californicus* remain doubtful based on questionable observations by various authors. It was determined that *T. californicus* had reduced egg production. Six weeks after *T. californicus* were brought

from the field and maintained in the laboratory with a diet of ice plant pollen and sugar water, nymphal stages were observed. The duration of the life cycle was substantially prolonged using ice plant pollen. Zaher and Shehata (1963) found that the larval stage of *T. californicus* lasted between 2.5 and 3.5 days, the quiescent period lasted 2 to 3 days, at an average temperature of 29.4 °C. Ice plant pollen and sugar (sucrose) water combined were effective for the survival but not for optimal mite development of *T. californicus*. The population of immature *T. californicus* in this study was still active when the colony was eliminated after two months. Adults were not present during that time. Ice plant pollen and sugar (sucrose) water prolonged the duration of the immature stages of *T. californicus* but apparently were not nutritionally adequate for adult development.

Tydeus californicus was described as *Tetranychoides californica* by Banks (1904) from material collected from the lower surface of orange leaves in California. Quayle (1912) found *T. californicus* in immense numbers (qualitative observation) on citrus trees in California but did not indicate when this occurred. Cast skins were arranged in a compact mass and the surface of the leaf was normal. The mites wandered about as they fed and appeared to come to definite resting sites only for the purpose of molting. The injury inflicted by this species was slight compared with the numbers that were present according to Quayle (1912). It was a ubiquitous and well known species and reported as predacious (Atalla et al. 1972), phytophagous (Fleschner & Arakawa 1952) or as a honeydew feeder (Bayan 1986).

Soliman et al. (1974) reared *T. californicus* on sweet potato in Egypt. He confirmed that the females gave birth to larvae without depositing eggs although some egg shells were observed on the leaves. This suggested that some females could lay eggs

which hatched soon after oviposition. Immature stages survived about 17.4 days at 29.5 °C and adults lived from 8.5 to 26.5 days and then died without ovipositing or producing larvae. They concluded this could be due to an inadequate substrate for reproduction. Soliman et al. (1974) stated that sweet potato leaves were free from any animal nourishment or fungus but gave no information about the source of food used for developing the assay.

Wahab et al. (1974) reared *T. californicus* on *Ipomoea batatas* Poiret, *Duranta plumieri* Jacquin and *H. rosa-sinensis* in Egypt and reported the larvae "fed for a period", but did not indicate the food source. They also stated that this species had only two nymphal stages (proto and deutonymph), which was incorrect since the family Tydeidae also has a tritonymphal stage. Observations about the development of fertilized eggs inside the female were also indicated. They concluded that, when reared on *H. rosa-sinensis, T. californicus* lived longer, and produced more larvae. This may be due to the plant components favoring mite development. *Tydeus californicus* was abundant on perennial cotton (*Gossypium hirsutum* L.), where individuals were seen aggregating in high numbers on both sides of the leaves (Youssef et al. 1976).

Synthetic honeydew was not evaluated in these experiments. However, sugar (sucrose) water was used alone and in combination with ice plant pollen. There was a specific response to sugar (sucrose) water, even though this food source might be constituted by other compounds different from synthetic honeydew. Sugar (sucrose) water exerted an attraction to *L. formosa, T. californicus*, and *T. gloveri* as a food source in this study. Brickhill (1958) assessed synthetic honeydew (three grams of enzymatic protein hydrolyzate of yeast plus six grams of fructose) and determined that the

development of *L. ferulus* was completed using this type of food. *Tydeus bakeri* did not complete development like *L. ferulus* when synthetic honeydew was offered, as proof of the specific response to different food sources for different tydeid species.

Lorryia formosa fed on cattail and oak pollens as well, though they apparently were less attractive than ice plant pollen. Flaherty and Hoy (1971) reported that *H. anconai* could be successfully reared on pollens of *Melaleuca hypericifolia* Smith, *V. vinifera*, and *Typha* sp. Knop and Hoy (1983a) determined that *H. anconai* was able to feed and reproduce on pollens of *Callistemon* sp., *C. chilensis*, *Magnolia* sp. and *Eschscholzia* sp. Their attraction to pollen was later corroborated by Hessein and Perring (1986), who concluded that *H. anconai* was able to feed on pollens of *C. citrinus*, *C. chilensis* and *T. latifolia*. Thus, various pollens are attractive to some tydeids and serve as a good food component.

Pseudolorryia mumai (Baker) was described by Baker (1970) as *Tydeus mumai* from a grapefruit leaf collected in Ft. Pierce, Florida. The author did not mention any associated damage caused by this mite nor its association with other organisms. No additional records are known in the literature. *Parapronematus acaciae* Baker was described by Baker (1965) from *Acacia* leaves collected in the former Belgian Congo (Democratic Republic of Congo today). Baker (1965) reported it on collections made by Muma from citrus in Polk County (Winter Haven, Lake Alfred, and Haines City) and St. Lucie County (Ft. Pierce), all in Florida. This mite was also collected from citrus in Hong Kong. Muma (1961,1965) first reported *P. acaciae* as a predator of the citrus rust mite, *P. oleivora*. However, when *P. citri*, *E. banksi*, and *P. oleivora* adults were offered as prey, *P. acaciae* failed to attack or consume any of the available adults of the three

species. In a subsequent study by McCoy et al. (1969), they did not provide immature mite stages or eggs as possible food sources for *P. acaciae*. They reported that *P. acaciae* was a fungal feeder completing four generations on *P. digitatum* and *C. gloeosporioides*, two commonly found leaf-inhabiting fungi in citrus trees. Muma (1975) reported *P. acaciae* as one of the most common tydeid mites on Florida citrus.

These studies demonstrated that *P. mumai* and *P. acaciae* were able to feed and reproduce on *Colletotrichum* sp. with colonies collected in the field and then maintained in the laboratory for over a month. In addition, fungal spores were found in the digestive tracts of both *L. formosa* and *T. californicus* and consisted of *Penicillium* sp. and *Colletotrichum* sp. *Tydeus gloveri* had spores of *Colletotrichum* sp. in their digestive tracts. These studies demonstrated the fungivorous nature of *P. mumai*, *P. acaciae*, *L. formosa*, *T. californicus*, and *T. gloveri* while *L. formosa* appears to have a greater diversity of food sources including a capacity to be predacious, saprophytic or fungivorous.

Tydeid mites were not found in association with *M. citri* or other citrus plant fungal pathogens in Florida. Neither *L. formosa* nor *P. acaciae* fed on *M. citri* mycelia that were offered, but they fed on other fungi. This demonstrated a specific attraction to certain fungi. However, we have no information about the status of citrus diseases and the tydeid fauna in other latitudes, e.g., the most humid areas of Asia where citrus is grown, such as in Indonesia, the Philippines, southern China, or in Tropical America. Many of these areas have a well defined wet season with high rainfall. *Pseudolorryia mumai* and *P. acaciae* were observed feeding and developing on mycelia produced by *Colletotrichum* sp. However, when this fungus was offered to *L. formosa*, there was no

observed feeding. Additional research is needed to fully evaluate the potential roles of Tydeidae in feeding on pathogenic and non-pathogenic fungi on citrus and other commodities. The tydeid affinity to fungal species has been reported by several authors. *Parapronematus acaciae* fed on *C. gloesporioides* and *P. digitatum* (McCoy et al. 1969); *H. anconai* on *C. cladosporioides* (Hessein & Perring 1986, 1988b) and *L. formosa* on sooty mold (Inserra 1967; Mendel & Gerson 1982). English-Loeb et al. (1999) reported the tydeid *T.* (*Orthotydeus*) *lambi* feeding on powdery mildew, *U. necator*, on both wild and domestic grapes. In a previous study, Flaherty and Hoy (1971) found *H. anconai* feeding on conidia of *U. necator*. However, very poor tydeid colonies developed, which contrasts with the observations made by English-Loeb et al. (1999) with *T. lambi*.

A sustained severe drought occurred between 1998 and 2000 in Florida. This affected the density of tydeids in the citrus orchards. It appears that fungi are an important component of certain tydeid diets, especially *L. formosa*, *T. californicus*, *T. gloveri*, *P. mumai* and *P. acaciae*. Dry conditions experienced in Florida between 1998 and 2000 are believed to have caused a direct negative effect on the abundance of tydeid mites, particularly *T. californicus*, considering that the drought might have had a negative affect on the presence and development of fungi, important food sources for this tydeid species.

Thoreau-Pierre (1977) described the role of *L. formosa* on citrus in Algeria and considered this species to be a detritus feeder. *Lorryia formosa* larval and adult stages were observed feeding on both their own exuviae and *Aleurodes* puparia. He also observed colonies of *L. formosa* associated with scale insects, feeding on the chorion whether the scale was alive or dead. He concluded that feeding by *L. formosa* was

associated with animal debris, especially related with chitin. *Lorryia formosa* was considered a beneficial organism, since it fed on animal debris and contributed to sanitization of the leaves (Thoreau-Pierre 1977). *Lorryia formosa* was also associated with the purple scale, *Lepidosaphes beckii* (Newman) (Homoptera: Diaspididae) (Thoreau-Pierre 1977). According to Ueckermann and Meyer (1979), *L. formosa* is attracted to honeydew excreted by scale insects and the subsequent accumulation of fungi upon which this species probably feeds. Mendel and Gerson (1982) as well as Thoreau-Pierre (1977) considered this species to be a sanitizing agent, since they observed, and later determined by experimentation, that *L. formosa* fed on sooty mold on citrus in Israel. Based on results from these studies, the exuviae were infested with *Colletotrichum* sp. and bacteria, which might be supplemental food sources.

Aculops pelekassi causes serious damage on citrus in Japan and is considered the most important eriophyid in that country (Seki 1979). In Florida, *A. pelekassi* causes significant economic damage to citrus fruit when weather conditions are favorable (Childers & Achor 1999).

Childers (1994) discussed the importance of studying tydeid mites on Florida citrus, and suggested that some species may offer considerable promise in the regulation of pest mites. *Lorryia formosa*, *P. mumai* and *T. gloveri* were evaluated as possible predators of the PCRM and only *L. formosa* showed a positive response. This was the first evidence of *L. formosa* preying on another mite species. Predation by *L. formosa* resembles that of Stigmaeidae mites, e.g., *Zetzellia mali* (Ewing), which apparently searches at random without any perception field and prey are located by tactile means (Santos & Laing 1985). Childers and Enns (1975) considered the stigmaeid mite

Agistemus fleschneri (Summers) as a slow and deliberate predator, when compared with phytoseiid mites, which is a similar behavior to that of *L. formosa*. Samarasinghe and Leroux (1966) reported a *Lorryia* species preying on the oyster shell scale on apples in Canada, but the tydeid was never identified. Because *A. pelekassi* is a pest on citrus, this finding should lead to further research to determine the role of *L. formosa* on Florida citrus and its potential for suppressing *A. pelekassi* populations. Hessein and Perring (1986) reported the predacious nature of the tydeid *H. anconai* on the tomato russet mite, *A. lycopersici* in California. *Homeopronematus anconai* was able to reduce this eriophyid to low densities on tomato leaflets while tomato plants without the predator turned yellow and died.

Phyllocoptruta oleivora was offered as prey to *L. formosa* in the same manner as *A. pelekassi*. However, no attempts of attacking or feeding on *P. oleivora* were observed. Reasons why *L. formosa* appeared to show preference for PCRM remain unknown. Studies are needed to determine whether physical or chemical barriers are involved.

Brickhill (1958) reported that *L. ferulus* fed on the eggs of *T. urticae*, but the eggs hatched later and produced viable larvae. In fact, *L. ferulus* likely was feeding only on surface contaminants of these eggs. In these studies, *L. formosa* was offered *P. citri* eggs. However, none of the mites were observed to even attempt feeding on these eggs, immatures or adults or on possible surface contaminants.

Neither Smirnoff (1957, 1959) nor Del Rivero (1962-1963) confirmed their conclusions with supporting histological or feeding studies, and incriminated *L. formosa* by speculation. *Lorryia formosa* is not a phytophagous mite and causes no harm to citrus trees based on the results of this study. These results demonstrated that *L. formosa*'s

feeding behavior is complex and it feeds on fungi, pollen, and honeydew released by homopteran insects, and the eggs and larvae of *A. pelekassi*.

Of the 9 species collected on several citrus surveys, itwas not possible to evaluate in their feeding habits of 4, i.e., *T. munsteri*, *P. shawi*, *Apopronematus* sp., and *Metapronematus* sp. The information about their feeding biology is scarce. For example, *Tydeus munsteri* was described by Meyer and Ryke (1959), who believed it was a predatory mite since it was found associated with *E. orientalis*. Meyer (1998) reported the association of *T. munsteri* with *E. orientalis*, and again considered *T. munsteri* being predacious on the spider mite but did not corroborate it with field or laboratory observations. According to records of the Division of Plant Industry in Gainesville, Florida, this species was collected in Florida in association with *Apis mellifera* L. (Hymenoptera: Apidae) in Umatilla, Lake County; on *Baccharis halimifolia* L. in Plymouth, Orange County; on *Quercus laurifolia* Michaux, and from citrus in Ft. Pierce, St. Lucie County and Port Salerno, Martin County (Welbourn, W.C. March, 2000, Florida Dept. Agriculture and Consumer Services, Division of Plant Industry, Gainesville. Personal communication). *Paralorryia shawi* was described by Baker (1943) as *Melanotydaeus shawi* from mosses and lichens on Popocateptl volcano, Puebla, Mexico at 2750 m above sea level; additional specimens were collected on lichens in Parque de Chapultepec, Mexico, Distrito Federal, and the Mexico-Cuernavaca road. Baker (1944) collected material from mosses and lichens on the road from Mexico to Cordoba, on the border with the State of Veracruz, February 1943; Valle del Bravo, Mexico, March 1943, and in the Hacienda Potrero Viejo, Veracruz, in February 1943. Their feeding habits are unknown, and species in this genus are always found in

association with lichens and mosses. *Apopronematus bakeri* André (André 1980) is another monotypic species collected from bark on grapes, var. Pinot noir and Sauvignon in the Napa Valley, California between 1969 and 1970 (André 1980). Besides the description of the species, there is no additional information available, but it is considered a bark dwelling species (André 1980). *Metapronematus leucohippeus* (Treat) was first described as *Pronematus leucohippeus* by Treat (1970), from the external tympanic recesses of *Epizeuxis aemula* Hübner (Lepidoptera: Noctuidae). André (1979) placed this species in *Metapronematus*. This species has not been reported since Treat's description.

Experiments are needed to fully evaluate *L. formosa*'s possible effect on *A. pelekassi* populations. For instance, the predatory rate of *L. formosa* should be evaluated. Determining how many PCRM eggs or immatures are consumed over defined time intervals by different tydeid species is an important step. *Lorryia formosa* was found in high numbers throughout much of the year (Chapter 4) and it occurred in all citrus habitats sampled, as well as on most ground cover plants sampled. Considering the densities found, *L. formosa* might be potentially significant in regulating PCRM, but more field and laboratory studies are needed to determine its role. Other potential food sources in combination with PCRM should be identified, as well as the evaluation of potential effects of feeding on fungi, including one or more pathogenic species.

In conclusion, *L. formosa*, *P. mumai*, *T. californicus*, *T. gloveri*, and *P. acaciae*, associated with citrus in Florida, have broad and complex feeding habits. One of the most important food components is fungi, which should be studied further since they appear to be a key factor in the maintenance of the Tydeidae populations.

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BIOGRAPHICAL SKETCH

Hugo Gerardo Aguilar-Piedra was born on 20 June 1959 in San Isidro de El General, province of San José, Costa Rica. He did his undergraduate studies at the University of Costa Rica in San José, and graduated in 1984 with a bachelor's degree in plant science. In 1986, Hugo defended his bachelor's thesis and obtained another degree in agronomy, with an emphasis in acarology. In 1987, he accepted a faculty position in acarology in the School of Plant Science, Faculty of Agronomy, University of Costa Rica. He taught acarology for five years and conducted investigations related with diagnosis, ecology and control of mites in several commodities, especially strawberries and ornamental plants, both foliage and flowers. He also worked closely with farmers throughout Costa Rica, helping them with their mite problems.

Hugo resigned from his faculty position at the University on December, 1991, when he was offered a research assistantship to conduct his master's studies on mite infestations related with azuki bean, at Washington State University, in Pullman, WA, in 1992, earning his MS degree in entomology in spring, 1995. During the first semester of 1995, he continued in Pullman working in practical training related to mite damage on potatoes; he moved to Florida on June, 1995, where he worked in another practical training, on mite citrus problems this time, for another semester. He began his PhD studies at the University of Florida in spring, 1996. Hugo will return to Costa Rica to fulfill an offered faculty position in acarology, at the Faculty of Agronomy, University of Costa Rica, in San José.

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

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